### The Simplest SAT Model of Combining Matsui's Bounding Conditions with Sequential Encoding Method

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Abstract. As the first generic method for finding the optimal differen-1 tial and linear characteristics, Matsui's branch and bound search algo-2 rithm has played an important role in evaluating the security of sym-3 metric ciphers. By combining the Matsui's bounding conditions with 4 automatic search models, the search efficiency can be improved. All the previous methods realize the bounding conditions by adding a set of constraints. This may increase the searching complexity of models. In this 7 paper, by using Information Theory to quantify the effect of bounding 8 conditions, we give the general form of bounding conditions that can use g all the information provided by Matsui's bounding conditions. Then, a 10 new method of combining bounding conditions with sequential encoding 11 method is proposed. Different from all the previous methods, our new 12 method can realize the bounding conditions by removing the variables 13 and clauses from Satisfiability Problem (SAT) models based on the orig-14 inal sequential encoding method. With the help of some small size Mixed 15 Integer Linear Programming (MILP) models, we build the simplest SAT 16 model of combining Matsui's bounding conditions with sequential en-17 coding method. Then, we apply our new method to search the optimal 18 differential and linear characteristics of some SPN, Feistel, and ARX 19 block ciphers. The number of variables, clauses and the solving time of 20 the SAT models are decreased significantly. And we find some new differ-21 ential and linear characteristics covering more rounds. For example, the 22 optimal differential probability of the full rounds GIFT128 is obtained 23 for the first time. 24

 Keywords: Automatic search · SAT model · Matsui's bounding condition · Differential cryptanalysis · Linear cryptanalysis

### 27 1 Introduction

<sup>28</sup> Differential [BS90] and linear [Mat93] cryptanalysis are two powerful methods
<sup>29</sup> which have been widely used in the security analysis of many symmetric ciphers.
<sup>30</sup> The core idea of these methods is to identify the differential or linear trails
<sup>31</sup> with high probability or correlation. However, searching the optimal differential

or linear trails is not an easy work. At EUROCRYPT 1994, Matsui [Mat94] 32 proposed a branch and bound search algorithm which can be used to identify the 33 optimal differentials with the maximum probability. Matsui's algorithm is one 34 of the most powerful and efficient search tools. However, implementing it needs 35 sophisticated programming skills when taking the cipher-specific optimizations 36 into consideration. In order to meet the demands of security analysis of ciphers, 37 many automatic search methods have been proposed and widely used in the 38 search of numerous distinguishers. 39

Mixed Integer Linear Programming (MILP) is a kind of optimization or fea-40 sibility program whose objective function and constraints are linear, and the 41 variables are restricted to be integers. MILP problem can be solved automati-42 cally with MILP solvers such as Gurobi [GRB]. In [WW11,MWGP11], the first 43 automatic search method based on MILP was proposed to evaluate the security 44 of word-oriented block ciphers against differential and linear cryptanalysis. Later, 45 Sun et al. [SHS<sup>+</sup>13,SHW<sup>+</sup>14] proposed methods for generating inequalities to de-46 scribe the bit-wise differential or linear characteristics of S-box. Therefore, their 47 models can be used to obtain the minimum number of active S-box and search 48 the best differential and linear characteristics of bit-oriented block ciphers. How-49 ever, the above methods only work on small size S-box (e.g. 4-bit). At FSE 2017, 50 Abdelkhalek et al. [AST<sup>+</sup>17] put forward the first MILP model for large S-box 51 (e.g. 8-bit). Then, some efficient methods were proposed to generate inequalities 52 of large S-box (e.g. [BC20,Udo21]). For ARX ciphers, Fu el al. [FWG<sup>+</sup>16] built 53 the MILP models for the differential and linear characteristics of modular addi-54 tion and applied them to search the best differential and linear characteristics 55 for SPECK. Moreover, as a powerful automatic search tool, MILP has been also 56 widely used in other attacks, such as integral attacks [XZBL16,WHG<sup>+</sup>19], cube 57 attacks [TIHM17], impossible differential attacks [ST17b], and zero-correlation 58 linear attacks [CJF<sup>+</sup>16]. 59

The Boolean Satisfiability Problem (SAT) is a problem which considers the 60 satisfiability of a given boolean formula. And there are also many SAT solvers, 61 such as CaDiCal [Bie19]. The first automatic search method based on SAT is 62 introduced by Mouha and Preneel [MP13]. Then, at CRYPTO 2015, Kölbl et 63 al. [KLT15] used the SAT/SMT solver to find the optimal differential and linear 64 characteristics for SIMON. And at ACNS 2016, Liu et al. [LWR16] extended 65 the SAT based automatic search algorithm to search the linear characteristics 66 for ARX ciphers. At FSE 2018, Sun et al. [SWW18] built the SAT-based mod-67 els for differential characteristics and got more accurate differential probability for LED64 and Midori64. Moreover, SAT can be used in searching impossible 69 differential trails [LLL<sup>+</sup>21] and integral distinguishers [SWW17]. 70

Unlike Matsui's algorithm, the automatic search tools enable cryptanalysts to
complete the search of distinguishers without sophisticated programming skills.
It brings great convenience to the security evaluation of ciphers. However, when
the number of variables or constrains in the model is large, the solver may not
return the result within a reasonable time. Therefore, it is of great importance

to improve the efficiency of automatic search method. And a lots of work havebeen done on this issue. We divide them into three main categories.

Reducing the Variables and Constraints in the Model. Although
Sasaki and Todo [ST17a] pointed out that the number of inequalities can not
strictly determinant the efficiency of solving model, it still has an important impact on the solving time. And a lot of methods have been proposed to reduce the
variables and constraints modeling S-box or linear layers [AST<sup>+</sup>17,BC20,Ud021].

**Divide and Conquer Approach.** In order to obtain the result of a large model in reasonable time, we can divide it into appropriate parts. In [SHW<sup>+</sup>14], Sun *et al.* split *r*-rounds cipher into the two parts (the first  $r_0$  and the last ( $r - r_0$ ) rounds). Then, they combined them after solving the models of the two parts respectively. At FSE 2019, Zhou *et al.* [ZZDX19] proposed a divideand-conquer approach which divide the whole searching space according to the number of active S-boxes at a certain round.

Combining Matsui's Bounding Conditions into the Model. Matsui's 90 bounding conditions may reduce the feasible region of the original model. The 91 first method of combining Matsui's branch and bound search algorithm with the 92 MILP based search model is proposed by Zhang et al. [ZSCH18]. Later, Sun et al. 93 [SWW21] put forward a new encoding method to convert the Matsui's bounding 94 conditions into boolean formulas of SAT model. Both methods are realized by 95 adding the constraints derived from the Matsui's bounding conditions into the 96 original model. 97

From the perspective of implementation effect, the SAT model combining 98 Matsui's bounding conditions proposed by Sun *et al.* [SWW21] is the best choice 99 at present. This method can obtain the complete bounds (full rounds) on the 100 number of active S-boxes, the differential probabilities and linear correlations 101 for many block ciphers for the first time. The efficiency of automatic search 102 has been greatly improved. Just like the MILP models of combining Matsui's 103 bounding conditions, according to the experiment results in [SWW21], adding 104 more Matsui's bounding conditions may not necessarily improve the efficiency. 105 This may because that all the previous methods realize the bounding conditions 106 by adding a set of constraints. And some added constrains increase the searching 107 complexity of models. Regrettably, there is no relevant theory for us to identify 108 the constrains which have negative effects. By doing a considerable amount of 109 experiments, Sun et al. put forward a strategy on how to organise the sets of 110 bounding conditions that potentially achieve better performance. Because this 111 strategy is experimental and lack sufficient theoretical guidance, we cannot really 112 know its performance until completing its application. Therefore, it is meaningful 113 to research the better way of combining Matsui's bounding conditions with the 114 automatic search models and improve the search efficiency. 115

### 116 1.1 Our Contributions

In this paper, we study the properties of Matsui's bounding conditions and the new way of combining Matsui's bounding conditions into the SAT model. The contributions of this paper are classified into the following three parts.

The Properties of Matsui's Bounding Conditions. Although we know 120 that the effect of Matsui's bounding conditions is to reduce the feasible region. 121 no one has been able to describe it accurately. By separating Matsui's bounding 122 conditions from specific ciphers, we use Information Theory to quantify the effect 123 of bounding conditions. Thus, when converting the bounding conditions into 124 other formula, we can evaluate the quality of the transformation. In this way, we 125 give the general form of inequality constraints that can utilize all the information 126 provided by Matsui's bounding conditions. 127

The Simplest SAT Model of Combining Matsui's Bounding Con-128 ditions with Sequential Encoding Method. Different from all the previous 129 methods, we propose a new method which can realize the Matsui's bounding 130 conditions by removing variables and constrains from the SAT model based on 131 sequential encoding method. This will decrease the solving complexity of mod-132 els. Then, with the help of some small size MILP models, we get the simplest 133 SAT model of combining Matsui's bounding conditions with sequential encoding 134 method which has the least variables and clauses. 135

Searching the Optimal Differential and Linear Characteristics of 136 Block Ciphers. We apply the simplest SAT model to search the optimal dif-137 ferential and linear characteristics of SPN, Feistel and ARX block ciphers. Com-138 pared with the previous method, the number of variables, clauses and the solving 139 time of the SAT models are decreased significantly which can be seen in Ta-140 ble 2. For block ciphers PRESENT, RECTANGLE, GIFT64, LBlock, TWINE, 141 SPECK32, SPECK64, the optimal differential and linear characteristics of the 142 full rounds are obtained which are consistent with the results in [SWW21]. For 143 SPECK48, SPECK96, SPECK128 and GIFT128, we find some new differential 144 and linear characteristics covering more rounds. For example, the optimal differ-145 ential probability of the full rounds GIFT128 is obtained for the first time. And a 146 comparison of the maximum length of optimal differential and linear trails with 147 previous results are provided in Table 1. For all the above ciphers, our results 148 reach the maximum length of optimal differential and linear trails at present. 149

Trail	GIFT128	SPECK48	SPECK96	SPECK128	Ref.
Differential	29	18	10	9	[SWW21]
	<b>40</b> (Full)	19	10	9	Sect. 5
Linear	25	23	14	10	[SWW21]
Linear	27	23	15	11	Sect. 5

Table 1. The comparison of the maximum length of optimal trails

### 150 1.2 Outline

This paper is organized as follows: Sect. 2 provides the background of automatic search method based on SAT. In Sect. 3, the properties of Matsui's bounding conditions are studied. In Sect. 4, we propose the simplest SAT model of combining bounding conditions with sequential encoding method. Sect. 5 uses the
new method to search the optimal differential and linear characteristics of block
ciphers. Sect.6 concludes the paper. And some auxiliary materials are supplied
in Appendix.

### <sup>158</sup> 2 Automatic Search Method Based on SAT

### 159 2.1 Boolean Satisfiability Problem

For a formula, if it only consists of boolean variables, operators AND ( $\wedge$ ), OR ( $\vee$ ), NOT ( $\overline{\cdot}$ ) and parentheses, we call it boolean formula. And SAT is the boolean satisfiability problem which considers whether there is a valid assignment to boolean variables such that the formula equals one. If such an assignment exists, the SAT problem is said satisfiable. It was shown that the problem is NPcomplete [Coo71]. However, many problem with millions of variables can be solved by modern SAT solvers, such as [Bie19].

For any boolean formula, we can convert it into Conjunctive Normal Form (CNF) denoted as  $\bigwedge_{i=0}^{m} \left( \bigvee_{j=0}^{n_i} c_{i,j} \right)$ , where  $c_{i,j}$  is a boolean variable or constant or the NOT of a boolean variable. And each disjunction  $\bigvee_{j=0}^{n_i} c_{i,j}$  is called a clause. Because CNF is a standard input format of SAT solvers. When using SAT to solve a problem, we have to translate it into a model consisted of boolean variables and clauses.

### 173 2.2 SAT Models for Some Basic Operations

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When we use SAT to search differential or linear characteristics, we should translate the search problem into a series of clauses. And the clauses should describe the propagation properties of differential or linear characteristics through the cipher. Here, we will briefly introduce the SAT models for some basic operations which will be used in this paper. For more information, please refer to [SWW21,LWR16]. And in the following, we use  $x_0$  to denote the most significant bit of the *n*-bit vector  $x = (x_0, x_1, \ldots, x_{n-1}) \in \mathbb{F}_2^n$ .

**Differential Model 1 (Branching)** [SWW21]. Let y = f(x) be a branching function, where  $x \in \mathbb{F}_2$  is the input variable, and the output variables  $y = (y_0, y_1, \ldots, y_{n-1}) \in \mathbb{F}_2^n$  is calculated as  $y_0 = y_1 = \cdots = y_{n-1} = x$ . Then,  $(\alpha, \beta_0, \beta_1, \ldots, \beta_{n-1})$  is a valid differential trail of f if and only if it satisfies all the equations in the following:

$$\left. \begin{array}{l} \alpha \lor \overline{\beta_i} = 1 \\ \overline{\alpha} \lor \beta_i = 1 \end{array} \right\}, 0 \le i \le n - 1.$$

**Differential Model 2 (Xor)** [SWW21]. Let y = f(x) be a function compressed by an Xor, where  $x = (x_0, x_1, \ldots, x_{n-1}) \in \mathbb{F}_2^n$  is the input variables, and the output variable  $y \in \mathbb{F}_2$  is calculated as  $y = x_0 \oplus x_1 \oplus \cdots \oplus x_{n-1}$ .

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When n = 2,  $(\alpha_0, \alpha_1, \beta)$  is a valid differential trail of f if and only if it satisfies all the equations in the following:

$$\begin{array}{c} \alpha_{0} \lor \alpha_{1} \lor \overline{\beta} = 1 \\ \alpha_{0} \lor \overline{\alpha_{1}} \lor \beta = 1 \\ \overline{\alpha_{0}} \lor \alpha_{1} \lor \beta = 1 \\ \overline{\alpha_{0}} \lor \overline{\alpha_{1}} \lor \overline{\beta} = 1 \end{array}$$

When  $n \ge 3$ , there are two main methods to model the Xor function. The first method decomposes the n-input Xor operation into (n-1) 2-input Xor operations by introducing auxiliary boolean variables  $u_0, u_1, \ldots, u_{n-3}$ . Then y = f(x) can be represented as the following 2-input Xor operations:

$$\begin{cases} x_0 \oplus x_1 = u_0; \\ x_i \oplus u_{i-2} = u_{i-1}, 2 \le i \le n-2; \\ x_{n-1} \oplus u_{n-3} = y. \end{cases}$$

After applying 2-input Xor model to the (n-1) 2-input Xor operations one by one, the model of n-input Xor operation can be expressed with  $4 \times (n-1)$  clauses. The second method does not introduce auxiliary boolean variables. Let A be the set  $\{(a_0, a_1, \ldots, a_n) \in \mathbb{F}_2^{n+1} | a_0 \oplus a_1 \oplus \ldots \oplus a_n = 1\}$ . Then, the differential trail  $(\alpha_0, \alpha_1, \ldots, \alpha_{n-1}, \beta)$  is valid if and only if it satisfies all the following equations.

 $(\alpha_0 \oplus a_0) \lor (\alpha_1 \oplus a_1) \lor \cdots \lor (\alpha_{n-1} \oplus a_{n-1}) \lor (\beta \oplus a_n) = 1, (a_0, a_1, \dots, a_n) \in A.$ 

According to [SLR<sup>+</sup>15], the linear masks propagation model for branching (resp. Xor) operation is the same as the differences propagation model for Xor (resp. branching) operation. Thus, we do not introduce the SAT models for linear mask propagation through branching and Xor operation.

**Differential Model 3 (Modular Addition)** [SWW21,LWR16]. Let z = f(x, y) be a n-bit modular addition operation. Then,  $(\alpha, \beta, \gamma) \in \mathbb{F}_2^{3 \times n}$  is a valid differential trail if and only if it satisfies all the following equations:

$$\begin{array}{l} \alpha_{n-1} \oplus \beta_{n-1} \oplus \gamma_{n-1} = 0; \\ \alpha_i \vee \beta_i \vee \overline{\gamma_i} \vee \alpha_{i+1} \vee \beta_{i+1} \vee \gamma_{i+1} = 1 \\ \alpha_i \vee \overline{\beta_i} \vee \gamma_i \vee \alpha_{i+1} \vee \beta_{i+1} \vee \gamma_{i+1} = 1 \\ \overline{\alpha_i} \vee \overline{\beta_i} \vee \gamma_i \vee \alpha_{i+1} \vee \beta_{i+1} \vee \gamma_{i+1} = 1 \\ \overline{\alpha_i} \vee \overline{\beta_i} \vee \overline{\gamma_i} \vee \overline{\alpha_{i+1}} \vee \overline{\beta_{i+1}} \vee \overline{\gamma_{i+1}} = 1 \\ \alpha_i \vee \overline{\beta_i} \vee \overline{\gamma_i} \vee \overline{\alpha_{i+1}} \vee \overline{\beta_{i+1}} \vee \overline{\gamma_{i+1}} = 1 \\ \overline{\alpha_i} \vee \beta_i \vee \overline{\gamma_i} \vee \overline{\alpha_{i+1}} \vee \overline{\beta_{i+1}} \vee \overline{\gamma_{i+1}} = 1 \\ \overline{\alpha_i} \vee \beta_i \vee \overline{\gamma_i} \vee \overline{\alpha_{i+1}} \vee \overline{\beta_{i+1}} \vee \overline{\gamma_{i+1}} = 1 \\ \overline{\alpha_i} \vee \overline{\beta_i} \vee \gamma_i \vee \overline{\alpha_{i+1}} \vee \overline{\beta_{i+1}} \vee \overline{\gamma_{i+1}} = 1 \\ \end{array} \right\} 0 \leq i \leq n-2.$$

where the Xor operation denoted by  $\oplus$  is symbolic representations which can be converted into CNF formulas with the method in Differential Model 2 (Xor). In order to model the different probability, we will introduce (n-1) binary variables denoted as  $w_0, w_1, \ldots, w_{n-2}$ . When they satisfy the following equations:

$$\begin{array}{l} \alpha_{i+1} \lor \gamma_{i+1} \lor w_i = 1 \\ \beta_{i+1} \lor \overline{\gamma_{i+1}} \lor w_i = 1 \\ \alpha_{i+1} \lor \overline{\beta_{i+1}} \lor w_i = 1 \\ \alpha_{i+1} \lor \beta_{i+1} \lor \gamma_{i+1} \lor \overline{w_i} = 1 \\ \hline \alpha_{i+1} \lor \overline{\beta_{i+1}} \lor \overline{\gamma_{i+1}} \lor \overline{w_i} = 1 \end{array} \right\} 0 \le i \le n-2,$$

the differential probability can be computed as  $p(\alpha, \beta, \gamma) = 2^{-\sum_{i=0}^{n-2} w_i}$ .

The papers [SWW21,LWR16] have showed the model for the linear correlations through modular addition. Because the most-significant bit of modular addition is a constant value, we can omit this variable. So we give a new linear model for modular addition which is a little different from the previous.

**Linear Model 1 (Modular Addition).** For n-bit modular addition operation z = f(x, y), we denote the two input linear masks as  $\alpha$  and  $\beta$  and the output mask as  $\gamma$ . And in order to model the correlation, (n-1) binary variables denoted as  $w = (w_0, w_1, \dots, w_{n-2})$  are introduced. Then, the correlation of the linear approximation  $(\alpha, \beta, \gamma) \in \mathbb{F}_2^{3 \times n}$  is nonzero if and only if  $(\alpha, \beta, \gamma, w)$ satisfies all the following equations:

$$\begin{array}{l} \alpha_0 \oplus \beta_0 \oplus \gamma_0 \oplus w_0 = 0; \\ \alpha_{j+1} \oplus \beta_{j+1} \oplus \gamma_{j+1} \oplus w_j \oplus w_{j+1} = 0, 0 \le j \le n-3; \\ \alpha_0 = \beta_0 = \gamma_0; \\ \alpha_i \lor \overline{\gamma_i} \lor w_{i-1} = 1 \\ \overline{\alpha_i} \lor \gamma_i \lor w_{i-1} = 1 \\ \beta_i \lor \overline{\gamma_i} \lor w_{i-1} = 1 \\ \overline{\beta_i} \lor \gamma_i \lor w_{i-1} = 1 \end{array} \right\} 1 \le i \le n-1.$$

Then, the linear correlation is computed as  $p(\alpha, \beta, \gamma) = 2^{-\sum_{i=0}^{n-2} w_i}$ .

For S-box, the paper [SWW18] showed an example of building the differential SAT model of 4-bit S-box. Then, the paper [SWW21] proposed the SAT model of active *n*-bit S-box. Based on the above two methods, we will show a general method for building SAT model of S-box.

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**Differential Model 4 (S-box).** For an S-box  $f : \mathbb{F}_2^n \to \mathbb{F}_2^m$ , the differential probability is denoted as  $p(\alpha, \beta)$ , where  $\alpha \in \mathbb{F}_2^n$  is the input difference and  $\beta \in \mathbb{F}_2^m$ is the output difference. If the minimal non-zero differential probability of S-box is  $2^{-s}$ , where s is an integer, we introduce s auxiliary variables  $w_0, w_1, \ldots, w_{s-1}$ satisfying  $w_{i+1} \leq w_i, 0 \leq i \leq s-2$  to calculate the non-zero differential probability. In order to build the differential SAT model of S-box, we introduce a boolean function as follows:

$$g(\alpha, \beta, w) = \begin{cases} 1, \text{ if } p(\alpha, \beta) = 2^{-\sum_{i=0}^{s-1} w_i}; \\ 0, \text{ otherwise.} \end{cases}$$

Let A be a set which contains all vectors satisfying g(a, b, c) = 0 denoted as

$$A = \{(a, b, c) \in \mathbb{F}_2^{n+m+s} | g(a, b, c) = 0\}$$

Then, the following |A| clauses form a primary differential SAT model of the
given S-box

$$\bigvee_{i=0}^{n-1} (\alpha_i \oplus a_i^l) \vee \bigvee_{j=0}^{m-1} (\beta_j \oplus b_j^l) \vee \bigvee_{k=0}^{s-1} (w_k \oplus c_k^l) = 1, (a^l, b^l, c^l) \in A.$$

where |A| is the number of vectors in the set A and  $(a^l, b^l, c^l), 0 \le l \le |A| - 1$  is the *l*-th vector in the set A.

Note that the solution space of the above |A| clauses about  $(\alpha, \beta, \gamma)$  is the same as that of the following boolean function:

$$h(\alpha,\beta,\gamma) = \bigwedge_{l=0}^{|A|-1} \left( \bigvee_{i=0}^{n-1} \left( \alpha_i \oplus a_i^l \right) \vee \bigvee_{j=0}^{m-1} \left( \beta_j \oplus b_j^l \right) \vee \bigvee_{k=0}^{s-1} \left( w_k \oplus c_k^l \right) \right) = 1.$$

Equivalently, we have

$$h(\alpha,\beta,\gamma) = \bigwedge_{(a,b,c)\in\mathbb{F}_2^{n+m+s}} \left( h(a,b,c) \lor \bigvee_{i=0}^{n-1} (\alpha_i \oplus a_i) \lor \bigvee_{j=0}^{m-1} (\beta_j \oplus b_j) \lor \bigvee_{k=0}^{s-1} (w_k \oplus c_k) \right).$$

This equation is called the product-of-sum representation of h. The issue of 245 reducing the number of clauses is turned into the problem of simplifying the 246 product-of-sum representation of the boolean function. According to  $[AST^+17]$ , 247 we know that this simplification problem can be solved by the Quine-McCluskey 248 (QM) algorithm and Espresso algorithm, theoretically. Although it is also an 249 NP-complete problem, the small-scale problem can be solved by some softwares, 250 such as Logic Friday<sup>3</sup>. After simplification, the SAT model characterising the 251 differential propagation through S-box can be established. 252

Using the same method of differential SAT model for S-box, the SAT model for linear correlations through S-box can be built easily. Here, we omit it.

### 255 2.3 Sequential Encoding Method

When we build SAT model of ciphers, we always aim at getting some cryptographic property such as the number of active S-boxes, the differential probability or the linear correlation. All kinds of these objections can be abstracted as the boolean cardinality constraint  $\sum_{i=0}^{n-1} w_i \leq m$ , where  $w_i$  is a boolean variable, and m is a non-negative integer. However, addition over integers is not a natural operation in SAT language, which is not easy to describe with only OR and AND

<sup>&</sup>lt;sup>3</sup> http://windows.dailydownloaded.com/en/educational-software/studenttools/44924-logic-friday-download-install

operations. The sequential encoding method is one of the best methods which can use relatively small amount of additional variables and a great reduction of clauses to characterise the constraint. Many papers [SWW21,SWW18,LWR16] use the sequential encoding method to convert the constraint into CNF formulas. When m = 0, the cardinality constraint  $\sum_{i=0}^{n-1} w_i \leq m$  can be translated to n clauses as  $\overline{w_i} = 1, 0 \leq i \leq n-1$  which means all variables are zero.

When  $m \ge 1$ , in order to model constraint  $\sum_{i=0}^{n-1} w_i \le m$ , auxiliary boolean variables  $u_{i,j}$   $(0 \le i \le n-2, 0 \le j \le m-1)$  are introduced to return contradiction when the cardinality is larger than m. More specifically, for the partial sum  $\sum_{i=0}^{k} w_i = m_k$ , the values of the auxiliary boolean variables  $u_{k,j}$   $(0 \le j \le m-1)$ should satisfy the following equations:

$$u_{k,j} = \begin{cases} 0, \text{ if } m_k \le j \le m-1; \\ 1, \text{ if } 0 \le j \le m_k - 1. \end{cases}$$

Then,  $\sum_{i=0}^{k} w_i = \sum_{j=0}^{m-1} u_{k,j}$ , and the sequence  $\left\{\sum_{i=0}^{k} w_i | 0 \le k \le n-2\right\}$  is non-decreasing. Therefore, the constraint  $\sum_{i=0}^{n-1} w_i \le m$  holds if the following implication predicates are satisfied.

$$\begin{array}{l} \text{if } w_0 = 1 \text{ then } u_{0,0} = 1 \\ u_{0,j} = 0, 1 \le j \le m - 1 \\ \text{if } w_i = 1 \text{ then } u_{i,0} = 1 \\ \text{if } u_{i-1,0} = 1 \text{ then } u_{i,0} = 1 \\ \text{if } w_i = 1 \text{ and } u_{i-1,j-1} = 1 \text{ then } u_{i,j} = 1 \\ \text{if } u_{i-1,j} = 1 \text{ then } u_{i,j} = 1 \\ \text{if } w_i = 1 \text{ then } u_{i-1,m-1} = 0 \\ \text{if } w_{n-1} = 1 \text{ then } u_{n-2,m-1} = 0 \end{array} \right\} 1 \le j \le m - 1 \\ \end{array} \right\} 1 \le i \le n - 2$$

The above predicates can be interpreted as the following  $2 \cdot m \cdot n - 3 \cdot m + n - 1$ clauses which are the SAT model for the cardinality constraint  $\sum_{i=0}^{n-1} w_i \leq m$ .

$$\overline{w_0} \lor u_{0,0} = 1 \overline{w_{0,j}} = 1, 1 \le j \le m - 1 \overline{w_i} \lor u_{i,0} = 1 \overline{w_i} \lor \overline{u_{i-1,j-1}} \lor u_{i,j} = 1 \overline{w_i} \lor \overline{u_{i-1,j-1}} \lor u_{i,j} = 1 \overline{w_i} \lor \overline{u_{i-1,m-1}} = 1 \overline{w_{n-1}} \lor \overline{u_{n-2,m-1}} = 1$$

## 278 2.4 Combining Matsui's Bounding Conditions with Sequential 279 Encoding Method

At EUROCRYPT 1994, Matsui [Mat94] proposed a branch and bound search algorithm which can be used to identify the optimal difference with the maximum probability. Let  $P_{ini}(R)$  be the initial estimation for the probability bound achieved by *R*-round trails. With the knowledge of  $P_{opt}(i)$ ,  $1 \le i \le R-1$ , where  $P_{opt}(i)$  is the maximum probability achieved by *i*-round trails, a partial trail  $(\alpha^0, \alpha^1, \ldots, \alpha^r), 1 \le r \le R-1$  covering the first *r* rounds will never extend to be a better *R*-round trial if it does not satisfy the following condition:

$$\prod_{i=0}^{r-1} p\left(\alpha^{i} \to \alpha^{i+1}\right) \cdot P_{opt}\left(R-r\right) \ge P_{ini}\left(R\right),\tag{1}$$

where  $p(\alpha^i \to \alpha^{i+1})$  is the probability of the *i*-th round. Therefore, we can give up the partial trail. In this way, the efficiency of search algorithm can be improved greatly.

Let  $-\log_2\left(p\left(\alpha^i \to \alpha^{i+1}\right)\right) = \sum_{j=0}^{\varpi-1} w_j^i$ , where  $w_j^i, 0 \le j \le \varpi - 1$  are the boolean variables used to calculate the probability weight of the trail propagation  $\alpha^i \to \alpha^{i+1}$ . By define the symbols  $n = r \cdot \varpi$  and  $w_{(\varpi \times i+j)} = w_j^i$ . Then, the Eq. (1) can be rewritten as follows:

$$\sum_{i=0}^{r-1} \sum_{j=0}^{\varpi-1} w_j^i = \sum_{i=0}^{n-1} w_i \le \log_2 \left( P_{opt} \left( R - r \right) \right) - \log_2 \left( Pr_{ini} \left( R \right) \right).$$
(2)

Note that the right-hand side of this equation is a constant, and the left-hand side of it matches the probability weight of the trail covering the first r rounds. Generally, all the above bounding conditions can be replaced with an inequality constraint of the following form:

$$\sum_{i=e_1}^{e_2} w_i \le m_{e_1,e_2}, 0 \le e_1 \le e_2.$$
(3)

Matsui's bounding conditions can be incorporated into automatic search algorithms. In [ZSCH18], Zhang *et al.* incorporated Matsui's bounding conditions into the MILP based automatic search of differential characteristics. Then, Sun *et al.* [SWW21] integrate Matsui's bounding conditions into the SAT method so that the search for optimal differential and linear characteristics can be accelerated. Here, we will introduce the SAT model of combining Matsui's bounding conditions with sequential encoding method.

For the boolean cardinality constraint  $\sum_{i=0}^{n-1} w_i \leq m$ , based on the sequential encoding method, Sun *et al.* realized bounding conditions without claiming any new variables as follows.

**Case 1.** Bounding condition  $\sum_{i=e_1}^{e_2} w_i \leq m_{e_1,e_2}$  with  $e_1 = 0$  and  $e_2 < n-1$ can be modeled by the following  $e_2$  clauses:

$$\overline{w_i} \lor \overline{u_{i-1,m_{e_1,e_2}-1}} = 1, 1 \le i \le e_2$$

**Case 2.** Bounding condition  $\sum_{i=e_1}^{e_2} w_i \leq m_{e_1,e_2}$  with  $e_1 > 0$  and  $e_2 < n-1$ can be modeled by the following  $m - m_{e_1,e_2}$  clauses:

$$u_{e_1-1,j} \vee \overline{u_{e_2,j+m_{e_1,e_2}}} = 1, 0 \le j \le m - m_{e_1,e_2} - 1.$$

**Case 3.** Bounding condition  $\sum_{i=e_1}^{e_2} w_i \leq m_{e_1,e_2}$  with  $e_1 > 0$  and  $e_2 = n-1$ can be modeled by the following  $2 \cdot (m - m_{e_1,e_2}) + 1$  clauses:

$$\begin{cases} u_{e_1-1,j} \lor \overline{u_{n-2,j+m_{e_1,e_2}}} = 1, \ 0 \le j \le m - m_{e_1,e_2} - 1; \\ u_{e_1-1,j} \lor \overline{w_{n-1}} \lor \overline{u_{n-2,j+m_{e_1,e_2}-1}} = 1, \ 0 \le j \le m - m_{e_1,e_2}. \end{cases}$$

The above method can intermix multiple Matsui's bounding conditions into one SAT problem with an increment on the number of clauses. At the same time, the number of variables remains the same as the original SAT model. According to the experiments, adding all the Matsui's bounding conditions into the SAT model is not the best choice. Thus, Sun *et al.* put forward a strategy on how to organise the sets of bounding conditions that potentially achieve better performance.

### 321 3 The Properties of Matsui's Bounding Conditions

We all know that the efficiency of Matsui's algorithm comes from the fact that it can eliminate some impossible solutions and reduce the search space. But, there is no relevant theory which can quantify this effect. In order to make better use of Matsui's bounding conditions, we will researching the properties of them.

### 326 3.1 Quantify the Effect of Matsui's Bounding Conditions

With the same mathematical symbols defined in Sect. 2, let  $w_i \in \mathbb{F}_2, 0 \le i \le n-1$ be the variables which are used to calculate the differential probability or linear correlation of a cipher. Because we want to study the nature of the Matsui's bounding conditions without considering the specific cryptographic algorithm. In order to avoid the influence of the specific cryptographic algorithm, we propose the definition of ideal cryptographic algorithm.

**Definition 1.** Let  $W = \{w^i \in \mathbb{F}_2^n, 0 \le i \le m-1\}$  be a cryptographic property vector set and E be a cipher. The event that E has property  $w^i \in W$  is denoted as  $E[w^i]$ . And the event that E does not has property  $w^i \in W$  is denoted as  $E[w^i]$ . Then, E is an ideal cipher of W if it satisfies the following conditions:

(1) For any vector  $w^i \in W$ , whether E has property  $w^i$  is random. That is, the probability of  $E[w^i]$  is  $\frac{1}{2}$ , denoted as  $p(E[w^i]) = \frac{1}{2}$ .

(2) For any two vectors  $w^i, w^j \in W, i \neq j, E[w^i]$  is independent with  $E[w^j]$ . That is  $p(E[w^i, w^j]) = p(E[w^i]) \times p(E[w^j]) = \frac{1}{4}$ , where  $E[w^i, w^j]$  is the event that E has the properties  $w^i$  and  $w^j$ .

If we obtain a Matsui's bounding condition  $\sum_{j=e_1}^{e_2} w_j \leq m_{e_1,e_2}$ , all the vectors which do not satisfy  $\sum_{j=e_1}^{e_2} w_j \leq m_{e_1,e_2}$  are not feasible cryptographic property. Thus, for vector  $w^i = (w_0^i, w_1^i, \dots, w_{n-1}^i)$  satisfying  $\sum_{j=e_1}^{e_2} w_j^i > m_{e_1,e_2}$ , we have  $p(E[w^i]) = 0$  and  $p(E[\overline{w^i}]) = 1$ . In order to quantify the effect of Matsui's bounding conditions, we introduce the Information Theory of Shannon [Sha48] firstly.

**Theorem 1.** [Sha48] For a set of possibilities  $P = \{p_0, p_1, \ldots, p_{n-1}\}$ , the information produced by P can be measured by  $H(P) = -\sum_{i=0}^{n-1} p_i \log_2^{p_i}$ .

Then, we use this theorem to measure the effect of Matsui's bounding conditions.

Lemma 1. Let E be an ideal cipher of a cryptographic property vector set  $W = \{w^i \in \mathbb{F}_2^n, 0 \le i \le m-1\}$  and  $C = \{C^0, C^1, \dots, C^{l-1}\}$  be a bounding conditions set. If there are N vectors of W which do not satisfy all the l conditions in C, the information of  $P = \{p(E[u^0, u^1, \dots, u^{m-1}]) | u^i \in \{w^i, \overline{w^i}\}, 0 \le i \le m-1\}$ decreased by C is N. And this property is denoted as  $H_d(P, C) = N$ .

Proof. Without considering the bounding conditions, we can apply Definition 1 and Theorem 1 to calculate the information of P as follows:

$$H(P) = -\sum_{u^i \in \{w^i, \overline{w^i}\}, 0 \le i \le m-1} p\left(E[u^0, u^1, \dots, u^{m-1}]\right) \log_2^{p\left(E[u^0, u^1, \dots, u^{m-1}]\right)} = -\sum_{u^i \in \{w^i, \overline{w^i}\}, 0 \le i \le m-1} 2^{-m} \log_2^{2^{-m}} = m.$$

When considering the l bounding conditions, if a vector  $w^i$  doesn't satisfying all the l bounding conditions, it cannot be the feasible cryptographic property. Without losing generality, we denote the N vectors which do not satisfy all the l conditions as  $\{w^i | 0 \le i \le N - 1\}$ . Then, we have

$$\begin{cases} p'\left(E[w^{i}]\right) = 0, & \text{if } 0 \le i \le N - 1; \\ p'\left(E[\overline{w^{i}}]\right) = 1, & \text{if } 0 \le i \le N - 1; \\ p'\left(E[w^{i}]\right) = \frac{1}{2}, & \text{if } N \le i \le m - 1; \\ p'\left(E[\overline{w^{i}}]\right) = \frac{1}{2}, & \text{if } N \le i \le m - 1. \end{cases}$$
(4)

362 For  $P' = \left\{ p'\left( E[u^0, u^1, \dots, u^{m-1}] \right) | u^i \in \{w^i, \overline{w^i}\}, 0 \le i \le m-1 \right\}$ , we have

$$H(P') = -\sum_{u^i \in \{w^i, \overline{w^i}\}, 0 \le i \le m-1} p' \left( E[u^0, u^1, \dots, u^{m-1}] \right) \log_2^{p' \left( E[u^0, u^1, \dots, u^{m-1}] \right)} \\ = -\sum_{u^i \in \{w^i, \overline{w^i}\}, N \le i \le m-1} 2^{-m+N} \log_2^{2^{-m+N}} = m - N.$$

The information of P decreased by C is  $H_d(P,C) = H(P) - H(P') = N$ .

When building SAT models, we have to convert the Matsui's bounding conditions into other form of formulas. In the following, we will evaluate the property of the transformation.

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**Lemma 2.** Let  $P = \left\{ p\left(E[u^0, u^1, \dots, u^{m-1}]\right) | u^i \in \{w^i, \overline{w^i}\}, 0 \le i \le m-1 \right\}$  be a cryptographic property possibilities set. If c is a bounding conditions set converted from the bounding conditions set C. Then, we have  $H_d(P, c) \le H_d(P, C)$ . *Proof.* Let  $w^i$  be a vector that satisfies all the bounding conditions in C. Because

**Proof.** Let  $w^i$  be a vector that satisfies all the bounding conditions in C. Because **c** is converted from C,  $w^i$  should also satisfies all the formulas in c. We have

$$m - H_d(P,C) \le m - H_d(P,c) \Rightarrow H_d(P,c) \le H_d(P,C).$$

**Corollary 1.** Let c be the bounding conditions set which is converted from the bounding condition set C. When  $H_d(P,c) = H_d(P,C)$ , all the information provided by bounding conditions set C has been fully utilized by c.

### 376 3.2 Further Insights into Matisui's Bounding Conditions

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According to Sect. 2.4, Sun *el al.* summarized all the Matsui's bounding conditions as the form of  $\sum_{i=e_1}^{e_2} w_i \leq m_{e_1,e_2}$ . However, when researching the information decreased by the constraints of the form  $\sum_{i=e_1}^{e_2} w_i \leq m_{e_1,e_2}$ , we find that they cannot always utilized all the information provided by Matusui's bounding conditions. We will give an example to show this phenomenon.

For a toy cipher *E* which has 3 rounds, let  $(\alpha^0, \alpha^1, \alpha^2, \alpha^3)$  be the 3-round trail. By introducing 6 boolean variables  $w = \{w_0^{(0)}, w_1^{(0)}, w_1^{(1)}, w_1^{(1)}, w_0^{(2)}, w_1^{(2)}\},$ the probability of round function is calculated as follows:

$$-\log_2\left(p\left(\alpha^i \to \alpha^{i+1}\right)\right) = w_0^{(i)} + w_1^{(i)}.$$
 (5)

Let  $P_{opt}(1) = 2^{-1}$ ,  $P_{opt}(2) = 2^{-2}$  and  $P_{ini}(3) = 2^{-3}$  be the Matsui's bounding conditions. Then, the vectors satisfying all the above 3 conditions are as follow:

 $\{0, 1, 0, 1, 0, 1\}, \{0, 1, 0, 1, 1, 0\}, \{0, 1, 1, 0, 0, 1\}, \{0, 1, 1, 0, 1, 0\}, \{1, 0, 0, 1, 0, 1\}, \{1, 0, 0, 1, 1, 0\}, \{1, 0, 1, 0, 0, 1\}, \{1, 0, 1, 0, 1, 0\}.$ 

Thus, the information decreased by  $\{P_{opt}(1), P_{opt}(2), P_{ini}(3)\}$  is  $2^6 - 8 = 56$ . According to Sect. 2.4, all the form of  $\sum_{i=e_1}^{e_2} w_i \leq m_{e_1,e_2}$  conditions deduced from Matsui's bounding conditions are as follows:

$$\begin{cases} C_{0}: -\log_{2}\left(p\left(\alpha^{0} \to \alpha^{1}\right)\right) \leq \log_{2}\left(P_{opt}\left(2\right)\right) - \log_{2}\left(P_{ini}\left(3\right)\right); \\ C_{1}: -\sum_{i=0}^{1}\log_{2}\left(p\left(\alpha^{i} \to \alpha^{i+1}\right)\right) \leq \log_{2}\left(P_{opt}\left(1\right)\right) - \log_{2}\left(P_{ini}\left(3\right)\right); \\ C_{2}: -\log_{2}\left(p\left(\alpha^{1} \to \alpha^{2}\right)\right) \leq 2 \cdot \log_{2}\left(P_{opt}\left(1\right)\right) - \log_{2}\left(P_{rini}\left(3\right)\right); \\ C_{3}: -\sum_{i=1}^{2}\log_{2}\left(P\left(\alpha^{i} \to \alpha^{i+1}\right)\right) \leq \log_{2}\left(P_{opt}\left(1\right)\right) - \log_{2}\left(P_{ini}\left(3\right)\right); \\ C_{4}: -\log_{2}\left(p\left(\alpha^{2} \to \alpha^{3}\right)\right) \leq \log_{2}\left(P_{opt}\left(2\right)\right) - \log_{2}\left(P_{ini}\left(3\right)\right); \\ C_{5}: -\sum_{i=0}^{2}\log_{2}\left(p\left(\alpha^{i} \to \alpha^{i+1}\right)\right) \leq -\log_{2}\left(P_{ini}\left(3\right)\right). \end{cases}$$
(6)

Combining Eq. (5) and Eq. (6), we have

$$\begin{cases} C_0': w_0^{(0)} + w_1^{(0)} \le 1; \\ C_1': w_0^{(0)} + w_1^{(0)} + w_0^{(1)} + w_1^{(1)} \le 2; \\ C_2': w_0^{(1)} + w_1^{(1)} \le 1; \\ C_3': w_0^{(1)} + w_1^{(1)} + w_0^{(2)} + w_1^{(2)} \le 2; \\ C_4': w_0^{(2)} + w_1^{(2)} \le 1; \\ C_5': w_0^{(0)} + w_1^{(0)} + w_0^{(1)} + w_1^{(1)} + w_0^{(2)} + w_1^{(2)} \le 3. \end{cases}$$

Then, the 27 vectors that satisfy all the conditions  $\{C'_0, C'_1, C'_2, C'_3, C'_4, C'_5\}$  are as follow:

 $\{0, 0, 0, 0, 0, 0\}, \{0, 0, 0, 0, 0, 1\}, \{0, 0, 0, 0, 1, 0\}, \{0, 0, 0, 1, 0, 0\}, \{0, 0, 0, 1, 0, 1\}, \\ \{0, 0, 0, 1, 1, 0\}, \{0, 0, 1, 0, 0, 0\}, \{0, 0, 1, 0, 0, 1\}, \{0, 0, 1, 0, 1, 0\}, \{0, 1, 0, 0, 0, 0\}, \\ \{0, 1, 0, 0, 0, 1\}, \{0, 1, 0, 0, 1, 0\}, \{0, 1, 0, 1, 0, 0\}, \{0, 1, 0, 1, 0, 1\}, \{0, 1, 0, 1, 1, 0\}, \\ \{0, 1, 1, 0, 0, 0\}, \{0, 1, 1, 0, 0, 1\}, \{0, 1, 1, 0, 1, 0\}, \{1, 0, 0, 0, 0, 0\}, \{1, 0, 0, 0, 0, 1\}, \\ \{1, 0, 0, 0, 1, 0\}, \{1, 0, 0, 1, 0, 0\}, \{1, 0, 0, 1, 0, 1\}, \{1, 0, 0, 1, 1, 0\}, \{1, 0, 1, 0, 0, 0\}, \\ \{1, 0, 1, 0, 0, 1\}, \{1, 0, 1, 0, 1, 0\}.$ 

That is, the information decreased by conditions  $\{C'_0, C'_1, C'_2, C'_3, C'_4, C'_5\}$  is  $2^6 - 27 = 37$ . Therefore, the bounding conditions  $\{C'_0, C'_1, C'_2, C'_3, C'_4, C'_5\}$  do not utilize all the information provided by  $\{P_{opt}(1), P_{opt}(2), P_{ini}(3)\}$ .

Here, we analyze the reasons for this phenomenon. When using Matsui's branch and bounding algorithm to search *R*-round optimal trails, we will firstly obtain a partial trail denoted as  $(\alpha^0, \alpha^1, \ldots, \alpha^r)$  covering the first *r* rounds. Then, we can use Eq. (1) to deduce the bound conditions of the form  $\sum_{i=e_1}^{e_2} w_i \leq m_{e_1,e_2}$ . But, it should be noted that all the obtained partial trails are valid. That is, the partial trials should satisfy

$$\sum_{i=0}^{r-1} -\log_2\left(p\left(\alpha^i \to \alpha^{i+1}\right)\right) \ge -\log_2\left(P_{opt}\left(r\right)\right).$$

<sup>402</sup> Therefore, when combining Matsui's bounding conditions with automatic search<sup>403</sup> algorithm, this kind of bounding conditions should also be considered.

**Theorem 2.** For an *R*-round cipher, the following bounding conditions can utilize all the information provided by  $M = \{P_{ini}(R), P_{opt}(i), 1 \le i \le R-1\}$ .

$$A_{j,r} : \sum_{i=j}^{r} \left( -\log_2 \left( p\left(\alpha^i \to \alpha^{i+1}\right) \right) \right) \le \log_2 \left( P_{opt}\left(j\right) \right) \\ +\log_2 \left( P_{opt}\left(R-1-r\right) \right) - \log_2 \left( P_{ini}\left(R\right) \right) \\ B_{j,r} : \sum_{i=j}^{r} \left( -\log_2 \left( p\left(\alpha^i \to \alpha^{i+1}\right) \right) \right) \ge -\log_2 \left( P_{opt}\left(r+1-j\right) \right) \right) \\ \end{bmatrix} \begin{array}{l} 0 \le j \le r, \\ r \le R-1. \end{array}$$

Proof. Let  $(\alpha^j, \alpha^{j+1}, \dots, \alpha^{r+1})$  be a feasible partial trail covering (r+1-j)rounds, where  $0 \le j \le r \le R-1$ . Because of the constraint  $P_{opt}(r+1-j)$ , the partial trail should satisfy the following bounding condition:

$$B_{j,r}: \sum_{i=j}^{r} \left( -\log_2\left(p\left(\alpha^i \to \alpha^{i+1}\right)\right) \right) \ge -\log_2\left(P_{opt}\left(r+1-j\right)\right).$$

Then, due to the constrain of  $P_{ini}(R)$ , the partial trail will also not be extended to better *R*-round trail if the following bounding condition is violated

$$P_{opt}(j) \cdot \prod_{i=j}^{r} \left( p\left(\alpha^{i} \to \alpha^{i+1}\right) \right) \cdot P_{opt}\left(R-1-r\right) \leq P_{ini}\left(R\right).$$

411 And the above bounding condition can be converted into

$$A_{j,r}: \sum_{i=j}^{r} \left(-\log_2\left(p\left(\alpha^i \to \alpha^{i+1}\right)\right)\right) \le \log_2\left(P_{opt}\left(j\right)\right) + \log_2\left(P_{opt}\left(R-1-r\right)\right) - \log_2\left(P_{ini}\left(R\right)\right).$$

That is, the bounding conditions  $\{A_{j,r}, B_{j,r}|0 \le j < r \le R-1\}$  is converted from  $M = \{P_{ini}(R), P_{opt}(i), 1 \le i \le R-1\}$ . According to Lemma 2, we have

$$H_d(P, \{A_{j,r}, B_{j,r} | 0 \le j \le r \le R - 1\}) \le H_d(P, M).$$
(7)

Let  $(\alpha^0, \alpha^1, \ldots, \alpha^R)$  be a trail which does not satisfy all the Matsui's bounding conditions in M. If  $(\alpha^0, \alpha^1, \ldots, \alpha^R)$  does not satisfy  $P_{ini}(R)$ , it will not satisfy  $A_{0,R-1}$ . If  $(\alpha^0, \alpha^1, \ldots, \alpha^R)$  satisfies  $P_{ini}(R)$ , there is at least a partial trail covering k round that does not satisfy  $P_{opt}(k)$ . We denote this partial trail as  $(\alpha^j, \alpha^{j+1}, \ldots, \alpha^{j+k})$ . Then, this partial trail will violate the bounding condition  $B_{j,j+k-1}$ . So the trail  $(\alpha^0, \alpha^1, \ldots, \alpha^R)$  will not satisfy all the bounding conditions in  $\{A_{j,r}, B_{j,r} | 0 \le j < r \le R - 1\}$ . Therefore, we have

$$H_d(P, \{A_{j,r}, B_{j,r} | 0 \le j < r \le R - 1\}) \ge H_d(P, M).$$
(8)

421 Combining Eq. (7) and Eq. (8), we have

$$H_d(P, \{A_{j,r}, B_{j,r} | 0 \le j < r \le R - 1\}) = H_d(P, M)$$

According to Corollary 1, the conditions set  $\{A_{j,r}, B_{j,r}|0 \leq j < r \leq R-1\}$ utilizes all the information provided by  $\{P_{ini}(R), P_{opt}(i), 1 \leq i \leq R-1\}$ .

424 Using the same mathematical symbols with Eq. (3), we have the following corol-425 lary.

**426** Corollary 2. All the Matsui's bounding conditions can be replaced with inequal-**427** ity constraints of the form  $l_{e_1,e_2} \leq \sum_{i=e_1}^{e_2} w_i \leq m_{e_1,e_2}$ .

# 428 4 The Simplest SAT Model of Combining Bounding 429 Conditions with Sequential Encoding Method

Although numerous Matsui's bounding conditions can be obtained, it is not sure
which bounding condition can accelerate the solve efficiency of SAT model accurately. With the observations and experiences in the tests, Sun *et al.* [SWW21]
put forward a strategy on how to create the sets of bounding conditions that
probably achieve extraordinary advances. But this is an experimental and heuristic strategy. It is worth studying how to combine bounding conditions with sequential encoding method in a better way.

## 437 4.1 A New Method of Combining Bounding Conditions with 438 Sequential Encoding Method

According to Sec. 2.3, in order to model the cardinality constraint  $\sum_{i=0}^{n-1} w_i \leq m$ , the normal sequential encoding method needs  $(n-1) \cdot m$  auxiliary variables, denoted as  $u_{i,j}$  ( $0 \leq i \leq n-2, 0 \leq j \leq m-1$ ). Then, the paper [SWW21] intermix the bounding conditions  $\sum_{i=e_1}^{e_2} w_i \leq m_{e_1,e_2}$  into the sequential encoding method by adding corresponding clauses. Different from the above strategy, we will propose a new method of intermixing multiple Matsui's bounding conditions into the sequential encoding method by removing some variables and clauses.

From Corollary 2, we know that the more general form of bounding condition is  $l_{e_1,e_2} \leq \sum_{i=e_1}^{e_2} w_i \leq m_{e_1,e_2}$ . If we get the condition  $l_{0,e_2} \leq \sum_{i=0}^{e_2} w_i \leq m_{0,e_2}$ , according to the rules of sequential encoding method, we have

$$u_{e_2,j} = \begin{cases} 0, & \text{if } m_{0,e_2} \le j \le m-1, \\ 1, & \text{if } 0 \le j \le l_{0,e_2} - 1, \\ uncertain, & \text{otherwise.} \end{cases}$$

Therefore, the value of some auxiliary variables are determine. We can omit the variables and clauses which characterise these determined values. Because there are at least  $m_{0,e_2} - l_{0,e_2}$  auxiliary variables whose values are uncertain. We have to introduce the boolean variables denoted as  $\{u_{e_2,j}|l_{0,e_2} \leq j \leq m_{e_2} - 1\}$  to represent these uncertain values. Then, we can use the following equation to compute the partial sum of  $\sum_{i=0}^{e_2} w_i$ .

$$\sum_{i=0}^{e_2} w_i = \sum_{j=l_{0,e_2}}^{m_{0,e_2}-1} u_{e_2,j} + l_{0,e_2}.$$

Base on this idea, we propose a new method of combining bounding conditionswith sequential encoding method.

**Lemma 3.** Let  $\sum_{i=0}^{n-1} w_i \leq m, 1 \leq n$  be a cardinality constraint. Based on the sequential encoding method, the following clauses can utilized all the information

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**459** provided by the condition  $l_{0,0} \le w_0 \le m_{0,0}$ :

if 
$$l_{0,0} = 0$$
 and  $m_{0,0} = 1$ :  
 $\overline{w_0} \lor u_{0,0} = 1$   
if  $l_{0,0} = 0$  and  $m_{0,0} = 0$ :  
 $\overline{w_0} = 1$   
if  $l_{0,0} = 1$  and  $m_{0,0} = 1$ :  
 $w_0 = 1$ 

And this is the simplest model of using the sequential encoding method to characterise the bounding condition  $l_{0,0} \le w_0 \le m_{0,0}$ .

Proof. When using original sequential encoding method to model the cardinality constraint  $\sum_{i=0}^{n-1} w_i \leq m$ , we have to introduce m auxiliary boolean variables  $u_{0,0}, u_{0,1}, \ldots, u_{0,m-1}$  to represent to the value of partial sum  $w_0$ . Different from the method in Sect. 2.4, we can realise the bounding condition  $l_{0,0} \leq w_0 \leq m_{0,0}$ by removing variables and clauses as follows.

When  $l_{0,0} = 0$  and  $m_{0,0} = 1$ , only the value of  $u_{0,0}$  is uncertain. And all the values of other auxiliary variables  $u_{0,1}, u_{0,2}, \ldots, u_{0,m-1}$  are determined. We can remove all these determined variables and related clauses. Then, the value of partial sum  $w_0$  can be represented by the rules of sequential encoding method as  $\overline{w_0} \vee u_{0,0} = 1$ .

When  $l_{0,0} = m_{0,0} = 0$ , all the values of auxiliary variables are determined. Thus, no auxiliary variables need to be introduced. And the value of partial sum  $w_0$  can be represented as the clause  $\overline{w_0} = 1$ .

When  $l_{0,0} = m_{0,0} = 1$ , all the values of auxiliary variables are determined. Thus, all the auxiliary variables and related clauses can be removed. And the value of partial sum  $w_0$  can be represented as the clause  $w_0 = 1$ .

In the above three cases, all the introduced auxiliary variables are used to 478 represent the uncertain value and all the clauses are the rules of sequential 479 encoding method to determined the values of variables. They are all necessary 480 which can not be removed. Take  $l_{0,0} = m_{0,0} = 1$  as an example, if we remove the 481 clause  $w_0 = 1$ , the value of  $w_0$  that removed by bounding condition can not be 482 removed. It is contradictory to the state that clauses can use all the information 483 provided by the bounding condition. Therefore, this is the simplest model of 484 using the sequential encoding method to characterise the bounding condition 485  $l_{0,0} \le w_0 \le m_{0,0}.$ 486

Lemma 4. Let  $\sum_{i=0}^{n-1} w_i \leq m, 3 \leq n$  be a cardinality constraint. If the bounding condition  $l_{0,e_2-1} \leq \sum_{i=0}^{e_2-1} w_i \leq m_{0,e_2-1}, 1 \leq e_2 \leq n-2$  is known, the following clauses can utilized all the information provided by  $l_{0,e_2} \leq \sum_{i=0}^{e_2} w_i \leq m_{0,e_2}$ .

$$\begin{split} & \text{if } m_{0,e_2} = 0: \\ & \overline{w_{e_2}} = 1 \\ & \text{if } m_{0,e_2} > 0: \\ & \text{if } l_{0,e_2} = 0: \\ & \overline{w_{e_2}} \lor u_{e_2,0} = 1 \\ & \text{if } l_{0,e_2-1} < m_{0,e_2-1}: \\ & \overline{w_{e_2} - 1,0} \lor u_{e_2,0} = 1 \\ & \text{if } j = l_{0,e_2-1}: \\ & \overline{w_{e_2}} \lor u_{e_2,j} = 1 \\ & \text{if } j > l_{0,e_2-1} \text{ and } j \leq m_{0,e_2-1}: \\ & \overline{w_{e_2}} \lor \overline{u_{e_2-1,j-1}} \lor u_{e_2,j} = 1 \\ & \text{if } j \geq l_{0,e_2-1} \text{ and } j \leq m_{0,e_2-1} - 1: \\ & \overline{u_{e_2-1,j}} \lor u_{e_2,j} = 1 \\ & \text{if } m_{0,e_2-1} = m_{0,e_2} \text{ and } l_{0,e_2-1} < m_{0,e_2}: \\ & \overline{w_{e_2}} \lor \overline{u_{e_2-1,m_{0,e_2}-1}} = 1 \\ & \text{if } l_{0,e_2-1} = m_{0,e_2}: \\ & \overline{w_{e_2}} = 1 \end{split}$$

And this is the simplest SAT model of using sequential encoding method to characterise the bounding condition  $l_{0,e_2} \leq \sum_{i=0}^{e_2} w_i \leq m_{0,e_2}$ .

Proof. When using original sequential encoding method to model the cardinality constraint  $\sum_{i=0}^{n-1} w_i \leq m$ , we have to introduce m auxiliary boolean variables  $u_{e_2,0}, u_{e_2,1}, \ldots, u_{e_2,m-1}$  to represent to the value of partial sum  $\sum_{i=0}^{e_2} w_i$ . Different from the method in Sect. 2.4, we can realise the bounding condition  $l_{0,e_2} \leq \sum_{i=0}^{e_2} w_i \leq m_{0,e_2}$  by removing variables and clauses as follows.

When  $m_{0,e_2} = 0$ , all the values of auxiliary variables are determined. Thus, all the auxiliary variables and related clauses can be removed. And the value of  $w_{e_2}$  can be represented as the clauses  $\overline{w_{e_2}} = 1$ .

When  $m_{0,e_2} > 0$ , in order to characterise the value of  $\sum_{i=0}^{e_2} w_i$ , the auxiliary variables  $m_{0,e_2} - l_{0,e_2}$  whose values are uncertain must be introduced, denoted as  $\{u_{e_2,j}|l_{0,e_2} \leq j \leq m_{0,e_2} - 1\}$ . And all the other auxiliary variables whose values are determined can be removed. Then, we use the rules of sequential encoding method to model these variables one by one.

If  $l_{0,e_2} = 0$ , the value of  $u_{e_2,0}$  should satisfy the following rules of sequential encoding method.

$$\begin{cases} \text{if } w_{e_2} = 1 \text{ then } u_{e_2,0} = 1; \\ \text{if } u_{e_2-1,0} \text{ is uncertain , when } u_{e_2-1,0} = 1 \text{ then } u_{e_2,0} = 1 \end{cases}$$

For  $max(l_{0,e_2},1) \leq j \leq m_{0,e_2}-1$ , the value of  $u_{e_2,j}$  should satisfy the following rules of sequential encoding method.

 $\begin{cases} \text{if } u_{e_2-1,j-1} \text{ is determined as 1 and } w_{e_2} = 1 \text{ then } u_{e_2,j} = 1; \\ \text{if } u_{e_2-1,j-1} \text{ is uncertain, when } u_{e_2-1,j-1} = 1 \text{ and } w_{e_2} = 1 \text{ then } u_{e_2,j} = 1; \\ \text{if } u_{e_2-1,j} \text{ is uncertain, when } u_{e_2-1,j} = 1 \text{ then } u_{e_2,j} = 1. \end{cases}$ 

Because of the bounding condition  $l_{0,e_2} \leq \sum_{i=0}^{e_2} w_i \leq m_{0,e_2}$  and the rules of sequential encoding method, auxiliary boolean variables  $u_{e_2,j}$  will return contradiction when  $\sum_{i=0}^{e_2} w_i > m_{0,e_2}$ . Thus, the following clauses should be satisfied.

$$\begin{cases} \text{if } m_{0,e_2-1} = m_{0,e_2}, u_{e_2-1,m_{0,e_2}-1} \text{ is uncertain, } w_{e_2} = 1 \text{ then } u_{e_2-1,m_{0,e_2}-1} = 0; \\ \text{if } l_{0,e_2-1} = m_{0,e_2} \text{ then } w_{e_2} = 0. \end{cases}$$

The above predicates can be interpreted as the clauses as Eq. (9). Moreover, because the values of  $u_{e_2,j}$ ,  $l_{0,e_2} \leq j \leq m_{e_2} - 1$  are uncertain. According to the rules of sequential encoding method, all these variables and corresponding clauses should not be omit. Therefore, this is the simplest model of using the sequential encoding method to characterise the bounding condition  $l_{0,e_2} \leq \sum_{i=0}^{e_2} w_i \leq m_{0,e_2}$ .

**Lemma 5.** For cardinality constraint  $\sum_{i=0}^{n-1} w_i \leq m, 2 \leq n$ , if the bounding condition  $l_{0,n-2} \leq \sum_{i=0}^{n-2} w_i \leq m_{0,n-2}$  is known, the following clauses can utilized all the information provided by the condition  $l_{0,n-1} \leq \sum_{i=0}^{n-1} w_i \leq m_{0,n-1}$ .

$$\begin{cases} \text{if } m_{0,n-1} = 0 : \\ \overline{w_{n-1}} = 1 \\ \text{if } m_{0,n-1} > 0 : \\ \text{if } m_{0,n-2} = m_{0,n-1} \text{ and } l_{0,n-2} < m_{0,n-1} : \\ \overline{w_{n-1}} \lor \overline{w_{n-2} - m_{0,n-1} - 1} = 1 \\ \text{if } l_{0,n-2} = m_{0,n-1} : \\ \overline{w_{n-1}} = 1 \end{cases}$$
(10)

And this is the simplest SAT model of using sequential encoding method to characterise the bounding condition  $l_{0,n-1} \leq \sum_{i=0}^{n-1} w_i \leq m_{0,n-1}$ .

Proof. According to Lemma 3 and 4, we know that the auxiliary variables  $u_{n-2,j}, l_{0,n-2} \leq j \leq m_{0,n-2} - 1$  is introduced to describe the value of  $\sum_{i=0}^{n-2} w_i$ . For the bounding condition  $l_{0,n-1} \leq \sum_{i=0}^{n-1} w_i \leq m_{0,n-1}$ , we only need to know whether the condition is valid or not. Therefore, no auxiliary variables need to be introduced. Then, the value of  $w_{n-1}$  should satisfy the following rules of sequential encoding method.

$$\begin{cases} \text{if } m_{0,n-1} = 0 \text{ then } w_{n-1} = 0; \\ \text{if } l_{0,n-2} < m_{0,n-1} = m_{0,n-2}, w_{n-1} = 1 \text{ then } u_{n-2,m_{0,n-1}-1} = 0; \\ \text{if } m_{0,n-1} > 0, l_{0,n-2} = m_{0,n-1} \text{ then } w_{n-1} = 0. \end{cases}$$

The above predicates can be interpreted as the clauses as Eq. (10). And all these clauses are the rules of sequential encoding method which can not be omit.  $\Box$ 

**Theorem 3.** Based on the sequential encoding method, the following clauses are the simplest SAT model which can use all the information provide by the bounding conditions  $l_{0,e_2} \leq \sum_{i=0}^{e_2} w_i \leq m_{0,e_2}, 0 \leq e_2 \leq n-1$ :

```
if l_{0,0} = 0 and m_{0,0} = 1:
     \overline{w_0} \vee u_{0,0} = 1
else if l_{0,0} = m_{0,0} = 0:
     \overline{w_0} = 1
else if l_{0,0} = 1 and m_{0,0} = 1:
     w_0 = 1
 if m_{0,e_2} = 0:
      \overline{w_{e_2}} = 1
 if m_{0,e_2} > 0:
      if l_{0,e_2} = 0:
            \overline{w_{e_2}} \lor u_{e_2,0} = 1
            if l_{0,e_2-1} < m_{0,e_2-1}:
                 \overline{u_{e_2-1,0}} \lor u_{e_2,0} = 1
             if j = l_{0,e_2-1}
             \begin{array}{c} \text{if } j = \iota_{0,e_{2}-1} \\ \overline{w_{e_{2}}} \lor u_{e_{2},j} = 1 \\ \text{if } j > l_{0,e_{2}-1} \text{ and } j \le m_{0,e_{2}-1} \\ \overline{w_{e_{2}}} \lor \overline{u_{e_{2}-1,j-1}} \lor u_{e_{2},j} = 1 \\ \text{if } j \ge l_{0,e_{2}-1} \text{ and } j \le m_{0,e_{2}-1} - 1 \\ \overline{u_{e_{2}-1,j}} \lor u_{e_{2},j} = 1 \end{array} \right\} \\ \begin{array}{c} max(l_{0,e_{2}},1) \le j \\ \le m_{0,e_{2}} - 1 \\ \end{array} \right. 
                                                                                                                                                1 \le e_2
                                                                                                                                                  \leq n-2
                                                                                                                                                                          (11)
      if m_{0,e_2-1} = m_{0,e_2} and l_{0,e_2-1} < m_{0,e_2}
            \overline{w_{e_2}} \lor \overline{u_{e_2-1,m_{0,e_2}-1}} = 1
      if l_{0,e_2-1} = m_{0,e_2}
            \overline{w_{e_2}} = 1
if m_{0,n-1} = 0:
     \overline{w_{n-1}} = 0
if m_{0,n-1} > 0:
     if m_{0,n-2} = m_{0,n-1} and l_{0,n-2} < m_{0,n-1}:
          \overline{w_{n-1}} \lor \overline{u_{n-2,m_{0,n-1}-1}} = 1
     if l_{0,n-2} = m_{0,n-1}:
          \overline{w_{n-1}} = 1
```

*Proof.* Any bounding condition  $l_{0,e_2} \leq \sum_{i=0}^{e_2} w_i \leq m_{0,e_2}$  belongs to only one case of Lemma 3-5. Therefore, we can integrate them into Eq. (11) which is the simplest SAT model based on sequential encoding method.

According to Theorem 3, the number of variables and clauses of the simplest SAT model of combining bounding conditions with sequential encoding method is only related to the upper bound and lower bound of partial sum  $\sum_{i=0}^{e_2} w_{e_2}, 0 \le e_2 \le n-1$ . Specifically, the total number of auxiliary variables needed is  $\sum_{i=0}^{n-2} (m_{0,i} - l_{0,i})$ . And after checking the generation rules of each clause in Eq. (11), we can easily get the following corollary.

**Corollary 3.** For two conditions sets  $\{l_{0,e_2} \leq \sum_{i=0}^{e_2} w_i \leq m_{0,e_2}, 0 \leq e_2 \leq n-1\}$ and  $\{L_{0,e_2} \leq \sum_{i=0}^{e_2} w_i \leq M_{0,e_2}, 0 \leq e_2 \leq n-1\}$ , if the inequalities  $l_{0,e_2} \geq L_{0,e_2}$ and  $m_{0,e_2} \leq M_{0,e_2}$  hold for all  $0 \leq e_2 \leq n-1$ , when using Theorem 3 to give their SAT models, the numbers of variables and clauses needed to characterise  $\{l_{0,e_2} \leq \sum_{i=0}^{e_2} w_i \leq m_{0,e_2}, 0 \leq e_2 \leq n-1\}$  will not more than those of  $\{L_{0,e_2} \leq \sum_{i=0}^{e_2} w_i \leq M_{0,e_2}, 0 \leq e_2 \leq n-1\}$ .

## 4.2 The Algorithm of Building Simplest SAT Model for Matsui's Bounding Conditions

When searching the best trail of *R*-round ciphers, we know the Matsui's proba-551 bility bounds  $P_{opt}(i), 1 \le i \le R-1$  and the initial estimation for the probability 552 bound of *R*-round trail  $P_{ini}(R)$ . According to Theorem 2, we can get a bounding 553 conditions set denoted as C which can utilize all the information provided by 554  $\{P_{ini}(R), P_{opt}(i), 1 \le i \le R-1\}$ . According to Corollary 3, if we get all the ac-555 curate bounds of partial sum  $\sum_{i=0}^{e_2} w_i, 0 \le e_2 \le n-1$  under the constraints of C, 556 then we can get the simplest model of combining Matsui's bounding conditions 557 set with sequential encoding method. In order to get the accurate lower bounds 558 and upper bounds of  $\sum_{i=0}^{e_2} w_i, 0 \le e_2 \le n-1$ , we will build some MILP models. 559 Here, we give the framework of getting the accurate bounds in Algorithm 1. 560

For usual ciphers, because the number of variables and constrains in Algorithm 1 is small, the time needed to solve these models is little. Therefore, for all partial sums  $\sum_{i=0}^{e_2} w_i, 0 \le e_2 \le n-1$ , we can use Algorithm 1 to get their accurate lower and upper bounds. Then, according to Theorem 3, the simplest SAT model of combining Matsui's bounding conditions and sequential encoding method can be obtained. And we can use it to search the best trails of *R*-round ciphers.

### 568 5 Applications to Block Ciphers

In this section, we apply the method for building simplest SAT model of combining Matsui's bounding conditions with sequential encoding method to several block ciphers. And we give a comparison with the primitive method of combining Matsui's bounding conditions with sequential encoding method proposed by Sun *et al.* [SWW21] on the number of variables, clauses and solving time. In order

Algorithm 1 Bound  $(C, w, \sum_{i=0}^{e_2} w_i)$ 

The bounding conditions set C; Input: The probability weight variables w; The partial sum  $\sum_{i=0}^{e_2} w_i$ . **Output:** The accurate lower bound  $l_{0,e_2}$  and upper bound  $m_{0,e_2}$  of  $\sum_{i=0}^{e_2} w_i$ . 1 Let  $\mathcal{M}_l$  be an empty MILP model for c in C do 2  $\mathcal{M}_l$ .addConstr(c) 3  $\mathcal{M}_l$ .setObjective $(\sum_{i=0}^{e_2} w_i, \text{GRB.MINIMIZE})$ 4  $l_{0,e_2} = \mathcal{M}_l.optimize()$ 5Let  $\mathcal{M}_m$  be an empty MILP model 6 for c in C do  $\overline{7}$ 8  $\mathcal{M}_m$ .addConstr(c)  $\mathcal{M}_m$ .setObjective $\left(\sum_{i=0}^{e_2} w_i, \text{GRB.MAXIMIZE}\right)$ 9  $10 \ m_{0,e_2} = \mathcal{M}_m.optimize()$ 11 return  $(l_{0,e_2}, m_{0,e_2})$ 

to make the comparison as fair as possible, we implement the two methods on the same platform (a PC with AMD Ryzen 9 5950X 16-Core 3.4G GHz) and the same SAT solver (CaDiCal [Bie19]).

### 577 5.1 Description of Some Block Ciphers

SPN Ciphers. PRESENT [BKL<sup>+</sup>07] has an SPN structure and uses 80and 128-bit keys with 64-bit blocks through 31 rounds. In order to improve the
hardware efficiency, it use a fully wired diffusion layer. RECTANGLE [ZBL<sup>+</sup>15]
is very like PRESENT. It is a 25-round SPN cipher with the 64-bit block size. As
an improved version of PRESENT, GIFT [BPP<sup>+</sup>17] is composed of two versions.
GIFT-64 is a 28-round SPN cipher with the 64-bit block size, and GIFT-128 is
a 40-round SPN cipher with the 128-bit block size.

Feistel Ciphers. LBlock [WZ11] is a lightweight block cipher proposed by
Wu and Zhang. The block size is 64 bits and the key size is 80 bits. It employs a
variant Feistel structure and consists of 32 rounds. And TWINE [SMMK12] is a
64-bit lightweight block cipher supporting 80- and 128-bit keys. It has the alike
structure as LBlock and consists of 36 rounds.

**ARX Ciphers.** SPECK [BSS<sup>+</sup>13] is a family of lightweight block ciphers published by National Security Agency (NSA). It adopts ARX structure which takes the modular addition as its nonlinear operation. According to block size, SPECK family of ciphers are composed of SPECK2*n*, where  $n \in \{16, 24, 32, 48, 64\}$ .

### 594 5.2 The Results of Applications

<sup>505</sup> In order to better illustrate our results, the following notations are introduced.

 $- M_{sun}$ : the method proposed by Sun *el al.* [SWW21].

23

- $-M_{sim}$ : the simplest method proposed in Sect. 4. 597
- Var, Cnf, T<sup>sol</sup>: the number of variables, clauses and solving time of models. 598
- $K_{var} = \frac{Var_{sim}}{Var_{sun}}$ : The ratio of the total number of variables.  $K_{cnf} = \frac{Cnf_{sim}}{Cnf_{sun}}$ : The ratio of the total number of clauses.  $K_{sol} = \frac{T_{sol}^{sol}}{T_{sol}^{sun}}$ : The ratio of the total solving time of models. 599
- 600
- 601
- $P_{opt}$ : the optimal probability of differential trails. 602
- Cor<sub>opt</sub>: the optimal correlation of linear trails. 603

We apply the two methods  $M_{sun}$  and  $M_{sim}$  to the above SPN, Feistel and 604 ARX ciphers to searching their optimal differential probabilities and linear cor-605 relations. The detailed results are shown in Table 4-14 in the Appendix. The 606 comparison of the two methods on the total number of variables, clauses and 607 solving time of models are presented in Table 2. According to the results, our 608 method have greater advantages. Take PRESENT as an example, when search-609 ing the optimal differential probabilities of every round from 1 to 31, the total 610 number of variables, clauses and the time of solving SAT models needed by our 611 method is only 7.1%, 11.1% and 36.6% of the method  $M_{sun}$ , respectively. 612

Cipher	Total round	Property	$K_{var}$	$K_{cnf}$	$K_{sol}$
PRESENT	31 (Full)	differential	7.1%	11.1%	36.6%
PRESENT	51 (Full)	linear	2.0%	4.7%	46.6%
RECTANGLE	25 (Full)	differential	16.2%	20.0%	35.0%
RECIANGLE	25 (Full)	linear	14.1%	27.4%	94.0%
GIFT64	28 (Full)	differential	8.7%	12.3%	44.8%
611 104	28 (Full)	linear	19.0%	24.1%	94.7%
GIFT128	29	differential	19.0%	22.9%	30.7%
GII 1120	25	linear	24.2%	28.5%	61.2%
LBlock	32 (Full)	differential	18.8%	52.5%	52.0%
LDIOCK	52 (Full)	linear	18.0%	31.8%	58.7%
TWINE	36 (Full)	differential	14.4%	19.6%	45.5%
	50 (Pull)	linear	18.0%	30.8%	60.0%
SPECK32	22 (Full)	differential	23.0%	28.5%	69.0%
SI ECK52	22 (Full)	linear	32.8%	43.0%	89.5%
SPECK48	18	differential	22.1%	33.5%	84.0%
51 ECK46	23 (Full)	linear	29.9%	39.5%	67.0%
SPECK64	27 (Full)	differential	18.3%	22.7%	76.5%
51 ECR04	27 (Puii)	linear	24.9%	34.2%	69.3%
SPECK96	10	differential	49.3%	54.5%	82.7%
51 EOR30	14	linear	47.2%	56.7%	67.8%
SPECK128	9	differential	51.8%	57.8%	90.3%
51 EUK120	10	linear	59.7%	68.3%	71.8%

Table 2. The comparison results of the two methods

For PRESENT, RECTANGLE, GIFT64, LBlock, TWINE, SPECK32 and 613 SPECK64, all the optimal differential probabilities and linear correlations of the 614

full-round ciphers have been obtained. For GIFT128, SPECK48, SPECK96 and SPECK128, our method  $M_{sim}$  finds some new differential probabilities or linear correlations covering more rounds which are listed Table 3.

Differential Property										
Cipher	Round	$\log_2^{P_{opt}}$	Var	Cnf	$T^{sol}$					
GIFT128	30	-193	838882	2119484	1548721.8s					
GIFT128	31	-198.415	473100	1176426	137815.9s					
GIFT128	32	-204.415	527361	1331711	191841.5s					
GIFT128	33	-210.415	523013	1331731	200005.4s					
GIFT128	34	-217.415	607170	1550500	242581.9s					
GIFT128	35	-224.83	627866	1601828	211591.8s					
GIFT128	36	-234.415	947853	2384355	1191166.5s					
GIFT128	37	-240.415	642079	1604643	258131.2s					
GIFT128	38	-246.415	633699	1596599	313064.2s					
GIFT128	39	-253.415	729939	1845704	115049.5s					
GIFT128	40	-260.415	644931	1633919	474680.7s					
SPECK48	19	-89	68632	177696	1736050.9s					
			ropert	У						
Cipher	Round	$\log_2^{Cor_{opt}}$	Var	Cnf	$T^{sol}$					
GIFT128	26	-91	147345	379885	3580030.2s					
GIFT128	27	-94	91807	236723	2274569.6s					
SPECK96	15	-43	50325	165960	268094.1s					
SPECK128	11	-31	55745	175540	939954.9s					

Table 3. New optimal differential probabilities and linear correlations

### 618 6 Conclusion

In this paper, we aim at finding a better way of combining Matsui's bounding 619 conditions with sequential encoding method. By quantifying the effect of bound-620 ing conditions, the general form of inequality constraint which can utilized all the 621 information provided by Matsui's bounding conditions are proposed. Because the 622 values of some auxiliary boolean variables in sequential encoding method can be 623 determined, we proposed a new method of integrating bounding conditions into 624 SAT model. Different from the previous methods, our new method can realize 625 the bounding conditions by removing variables and clauses. In order to accel-626 erate the search efficiency, the algorithm for building the simplest SAT model 627 of combining Matsui's bounding conditions with sequential encoding method is 628 proposed. When applying our new method to searching the optimal differential 629 probability and linear correlation of block ciphers, the total number of variables, 630 clauses and solving time of SAT models are decreased. And we find some new 631 differential and linear characteristics covering more round. As a result, we obtain 632 a more efficient search tool. 633

Because our method of combining bounding condition with sequential encoding method is general, it can be used to search other kinds of distinguishers for ciphers. The wide applications will be done in the future. And for GIFT128, SPECK48, SPECK96 and SPECK128, some optimal differential probabilities or linear correlations of the full round cipher can not be obtained by the existing methods. How to speed up the search of these ciphers is a problem worth studying.

### 642 References

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### 827 Appendix

Differential Property									
Round $\log_2 P_{opt}$ $M_{sun}$ $M_{sim}$									
nound	log <sub>2</sub> I opt	Var	Cnf	$T^{sol}$	Var	Cnf	$T^{sol}$		
1	-2	669	3112	0.1s	667	3059	0.1s		
2	-4	668	2659	0.1s	472	2217	0.1s		
3	-8	4203	14763	0.2s	2443	10799	0.2s		
4	-12	7839	24564	0.3s	3739	15479	0.3s		
5	-20	32809	92575	3.7s	14973	53459	2.4s		
6	-24	22011	58386	2.2s	8491	29135	1.1s		
7	-28	29679	76683	2.4s	9211	32663	1.7s		
8	-32	38499	97428	2.8s	9931	36191	1.5s		
9	-36	48471	120621	3.0s	10651	39719	1.0s		
10	-41	80418	196930	3.9s	8999	31662	1.6s		
11	-46	98990	238786	8.1s	14923	52427	2.4s		
12	-52	150790	358715	32.4s	28420	97945	9.7s		
13	-56	107355	252813	5.4s	18889	64523	3.3s		
14	-62	209460	489035	28.9s	35040	118125	16.7s		
15	-66	145437	337053	10.0s	22861	76631	3.1s		
16	-70	164337	379110	18.8s	22717	78431	2.1s		
17	-74	184389	423615	8.3s	22573	80231	2.3s		
18	-78	205593	470568	6.4s	22429	82031	2.5s		
19	-82	227949	519969	5.1s	8334	29753	1.3s		
20	-86	251457	571818	7.1s	8334	30449	1.3s		
21	-90	276117	626115	7.6s	8334	31145	1.3s		
22	-96	508490	1148645	15.6s	28141	101795	4.0s		
23	-100	335511	755283	11.8s	27697	102995	4.6s		
24	-106	612280	1374005	33.3s	34129	117935	16.6s		
25	-110	400665	896547	17.2s	33397	118559	4.9s		
26	-116	725670	1619525	60.0s	40117	134075	36.3s		
27	-120	471579	1049907	31.8s	39097	134123	12.5s		
28	-124	505167	1123068	20.8s	14034	47405	1.4s		
29	-128	539907	1198677	18.2s	13746	47525	2.3s		
30	-132	575799	1276734	19.1s	13458	47645	4.9s		
31	-136	612843	1357239	10 9.	10170	47705			
	100	012010	1337239	18.3s	13170	47765	3.5s		
Total	100	7575051	17154948			47765 1895896	3.5s 147.3:		
Total	100	7575051		403.0s					
		7575051	17154948 near Prop	403.0s		1895896			
	log <sub>2</sub> Cor <sub>opt</sub>	7575051 Lir	17154948 near Prop $M_{sun}$	403.0s	539417	1895896 M <sub>sim</sub>	147.3		
Round	$\log_2 Cor_{opt}$	7575051 Lir Var	$\begin{array}{c} 17154948\\ \textbf{near Prop}\\ \hline M_{sun}\\ \hline Cnf \end{array}$	403.0s perty T <sup>sol</sup>	539417 Var	$\begin{array}{c} 1895896\\ \hline M_{sim}\\ Cnf \end{array}$	147.3		
Round	log <sub>2</sub> Cor <sub>opt</sub> -1	7575051 Lir Var 351	$\begin{array}{c} 17154948\\ \textbf{near Prop}\\ \hline M_{sun}\\ \hline Cnf\\ 1790 \end{array}$	403.0s perty T <sup>sol</sup> 0.6s	539417 Var 351	$\begin{array}{c} 1895896\\ \hline M_{sim}\\ \hline Cnf\\ 1758 \end{array}$	$\begin{array}{c} 147.3 \\ \hline T^{sol} \\ 0.1 \\ \end{array}$		
Round 1 2	log <sub>2</sub> Cor <sub>opt</sub> -1 -2	7575051 Lir Var 351 382	$\begin{array}{c} 17154948 \\ \hline {\bf near \ Prop} \\ \hline M_{sun} \\ \hline Cnf \\ 1790 \\ 1977 \end{array}$	403.0s perty T <sup>sol</sup> 0.6s 0.4s	539417 Var 351 318	$\frac{M_{sim}}{Cnf} \\ 1758 \\ 1817$	147.3 $T^{sol}$ 0.1 0.1s		
$\frac{1}{2}$	$\frac{\log_2 Cor_{opt}}{-1}$ $-2$ $-4$	7575051 Lir Var 351 382 1369	$\begin{array}{c} 17154948 \\ \hline \mathbf{near \ Prop} \\ \hline M_{sun} \\ \hline Cnf \\ 1790 \\ 1977 \\ \hline 6599 \end{array}$	403.0s <b>perty</b> T <sup>sol</sup> 0.6s 0.4s 0.7s	539417 Var 351 318 983	$\frac{M_{sim}}{Cnf} \\ 1758 \\ 1817 \\ 5634$	$   \begin{array}{r} 147.3 \\         \hline         T^{sol} \\         0.1s \\         0.1s \\         0.1s \\         0.1s \\         \end{array} $		
Round 1 2 3 4	$log_2 Cor_{opt}$ -1 -2 -4 -6	7575051 Lir Var 351 382 1369 2293	$\begin{array}{c} 17154948 \\ \textbf{near Prop} \\ \hline M_{sun} \\ \hline Cnf \\ 1790 \\ 1977 \\ 6599 \\ 9945 \\ \end{array}$	$\begin{array}{c} 403.0 \text{s} \\ \hline \\ \textbf{perty} \\ \hline \\ T^{sol} \\ 0.6 \text{s} \\ 0.4 \text{s} \\ 0.7 \text{s} \\ 0.7 \text{s} \\ \hline \end{array}$	539417 Var 351 318 983 1391	$\frac{M_{sim}}{Cnf}\\ 1758\\ 1817\\ 5634\\ 7754$	$\begin{array}{c} 147.3 \\ \hline T^{sol} \\ 0.1 \\ 0.1 \\ 0.1 \\ 0.1 \\ 0.1 \\ \end{array}$		
$\begin{array}{c} \text{Round} \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \end{array}$		7575051 Lir Var 351 382 1369 2293 3473	$\begin{array}{c} 17154948 \\ \hline \textbf{mear Prop} \\ \hline M_{sun} \\ \hline Cnf \\ 1790 \\ 1977 \\ 6599 \\ 9945 \\ 13867 \\ \end{array}$	$\begin{array}{c} 403.0 \text{s} \\ \hline \\ \textbf{perty} \\ \hline \\ T^{sol} \\ 0.6 \text{s} \\ 0.6 \text{s} \\ 0.4 \text{s} \\ 0.7 \text{s} \\ 0.7 \text{s} \\ 0.7 \text{s} \end{array}$	539417 Var 351 318 983 1391 1799	$\frac{M_{sim}}{Cnf}\\ 1758\\ 1817\\ 5634\\ 7754\\ 9874$	$\begin{array}{c} 147.3 \\ \hline T^{sol} \\ 0.1 \\ 0.1 \\ 0.1 \\ 0.1 \\ 0.1 \\ 0.2 \\ s \\ 0.2 \\ s \end{array}$		
$\begin{array}{c} \text{Round} \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \end{array}$	log <sub>2</sub> Cor <sub>opt</sub> -1 -2 -4 -6 -8 -10	7575051 Lir Var 351 382 1369 2293 3473 4909	$\begin{array}{c} 17154948 \\ \textbf{near Prop} \\ \hline M_{sun} \\ \hline Cnf \\ 1790 \\ 1977 \\ 6599 \\ 9945 \\ 13867 \\ 18365 \end{array}$	$\begin{array}{c} 403.0 \text{s} \\ \hline \\ \mathbf{Derty} \\ \hline \\ T^{sol} \\ 0.6 \text{s} \\ 0.4 \text{s} \\ 0.7 \text{s} \\ 0.7 \text{s} \\ 0.7 \text{s} \\ 1.0 \text{s} \\ \end{array}$	539417 Var 351 318 983 1391 1799 2207	$\begin{array}{c} 1895896\\ \hline \\ M_{sim}\\ \hline Cnf\\ 1758\\ 1817\\ 5634\\ 7754\\ 9874\\ 11994 \end{array}$	$\begin{array}{c} 147.3 \\ \hline T^{sol} \\ 0.1 \\ 0.1 \\ 0.1 \\ 0.1 \\ 0.1 \\ 0.2 \\ 0.3 \\ \end{array}$		
$\begin{array}{c} \text{Round} \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \end{array}$	log <sub>2</sub> Cor <sub>opt</sub> -1 -2 -4 -6 -8 -10 -12	7575051 Lir Var 351 382 1369 2293 3473 4909 6601	$\begin{array}{c} 17154948 \\ \textbf{near Prop} \\ \hline M_{sun} \\ \hline Cnf \\ 1790 \\ 1977 \\ 6599 \\ 9945 \\ 13867 \\ 18365 \\ 23439 \end{array}$	$\begin{array}{c} 403.0 \mathrm{s} \\ \hline \\ \mathbf{Derty} \\ \hline \\ T^{sol} \\ 0.6 \mathrm{s} \\ 0.7 \mathrm{s} \\ 0.7 \mathrm{s} \\ 0.7 \mathrm{s} \\ 0.7 \mathrm{s} \\ 1.0 \mathrm{s} \\ 1.2 \mathrm{s} \end{array}$	$539417 \\ \hline Var \\ 351 \\ 318 \\ 983 \\ 1391 \\ 1799 \\ 2207 \\ 2615 \\ \hline$	$\begin{array}{c} M_{sim} \\ \hline M_{sim} \\ \hline Cnf \\ 1758 \\ 1817 \\ 5634 \\ 7754 \\ 9874 \\ 11994 \\ 14114 \end{array}$	$\begin{array}{c} 147.3 \\ \hline T^{sol} \\ 0.1 \\ 0.1 \\ 0.1 \\ 0.1 \\ 0.2 \\ 0.3 \\ 0.4 \\ s \end{array}$		
$\begin{array}{c} \text{Round} \\ \hline 1 \\ \hline 2 \\ \hline 3 \\ \hline 4 \\ \hline 5 \\ \hline 6 \\ \hline 7 \\ \hline 8 \\ \end{array}$	$\begin{array}{c} \log_2 Cor_{opt} \\ -1 \\ -2 \\ -4 \\ -6 \\ -8 \\ -10 \\ -12 \\ -14 \end{array}$	7575051 Lir Var 351 382 1369 2293 3473 4909 6601 8549	$\begin{array}{c} 17154948\\ \textbf{near Prop}\\ \hline M_{sun}\\ \hline Cnf\\ 1790\\ 1977\\ \hline 6599\\ 9945\\ 13867\\ 18365\\ 23439\\ 29089\\ \end{array}$	$\begin{array}{c} 403.0 \text{s} \\ \hline \\ \textbf{perty} \\ \hline \\ \hline \\ \textbf{0.6s} \\ \hline \\ \textbf{0.7s} \\ \hline \\ \textbf{0.7s} \\ \hline \\ \textbf{0.7s} \\ \hline \\ \textbf{0.7s} \\ \hline \\ \textbf{1.2s} \\ \hline \\ \textbf{1.0s} \\ \hline \end{array}$	539417 Var 351 318 983 1391 1799 2207 2615 3023	$\begin{array}{c} M_{sim} \\ \hline M_{sim} \\ \hline Cnf \\ 1758 \\ 1817 \\ 5634 \\ 7754 \\ 9874 \\ 11994 \\ 14114 \\ 16234 \end{array}$	$\begin{array}{c} 147.3 \\ \hline T^{sol} \\ 0.1s \\ 0.1s \\ 0.1s \\ 0.1s \\ 0.2s \\ 0.3s \\ 0.4s \\ 0.4s \end{array}$		
Round 1 2 3 4 5 6 7 8 9	$\begin{array}{c} \log_2 Cor_{opt} \\ -1 \\ -2 \\ -4 \\ -6 \\ -8 \\ -10 \\ -12 \\ -14 \\ -16 \end{array}$	7575051 Lir Var 351 382 1369 2293 3473 4909 6601 8549 10753	$\begin{array}{c} 17154948\\ \textbf{near Prop}\\ \hline M_{sun}\\ \hline Cnf\\ 1790\\ 1977\\ 6599\\ 9945\\ 13867\\ 18365\\ 23439\\ 29089\\ 35315\\ \end{array}$	$\begin{array}{c} 403.0 \text{s} \\ \hline \\ \textbf{perty} \\ \hline \\ \hline \\ \textbf{0.6s} \\ \hline \\ \textbf{0.7s} \\ \hline \\ \textbf{0.7s} \\ \hline \\ \textbf{0.7s} \\ \hline \\ \textbf{0.7s} \\ \hline \\ \textbf{1.0s} \\ \hline \\ \textbf{1.1s} \end{array}$	539417 Var 351 318 983 1391 7799 2207 2615 3023 3431	$\begin{array}{c} M_{sim} \\ \hline \\ Cnf \\ 1758 \\ 1817 \\ 5634 \\ 7754 \\ 9874 \\ 11994 \\ 14114 \\ 16234 \\ 18354 \end{array}$	$\begin{array}{c} 147.3 \\ \hline T^{sol} \\ 0.1s \\ 0.1s \\ 0.1s \\ 0.1s \\ 0.2s \\ 0.3s \\ 0.4s \\ 0.4s \\ 0.7s \end{array}$		
Round 1 2 3 4 5 6 7 8 9 10	log <sub>2</sub> Cor <sub>opt</sub> -1 -2 -4 -6 -8 -10 -12 -12 -14 -16 -18	7575051 Lir Var 351 382 1369 2293 3473 4909 6601 8549 10753 13213	$\begin{array}{c} 17154948 \\ \textbf{near Prop} \\ \hline M_{sun} \\ \hline Cnf \\ 1790 \\ 1977 \\ 6599 \\ 9945 \\ 13867 \\ 18365 \\ 23439 \\ 29089 \\ 35315 \\ 42117 \end{array}$	$\begin{array}{c} 403.0 \mathrm{s} \\ \hline T^{sol} \\ 0.6 \mathrm{s} \\ 0.7 \mathrm{s} \\ 0.7 \mathrm{s} \\ 0.7 \mathrm{s} \\ 1.0 \mathrm{s} \\ 1.2 \mathrm{s} \\ 1.0 \mathrm{s} \\ 1.1 \mathrm{s} \\ 1.3 \mathrm{s} \end{array}$	539417 Var 351 318 983 1391 1799 2207 2615 3023 3431 3839	$\frac{M_{sim}}{Cnf}\\ \frac{Cnf}{1758}\\ 1758\\ 1817\\ 5634\\ 7754\\ 9874\\ 11994\\ 14114\\ 16234\\ 18354\\ 20474\\ \end{array}$	$\begin{array}{c} 147.3 \\ \hline T^{sol} \\ 0.1s \\ 0.1s \\ 0.1s \\ 0.1s \\ 0.2s \\ 0.3s \\ 0.4s \\ 0.4s \\ 0.7s \\ 0.8s \end{array}$		
Round 1 2 3 4 5 6 7 8 9 10 11	$\begin{array}{c} \log_2 Cor_{opt} \\ -1 \\ -2 \\ -4 \\ -6 \\ -8 \\ -10 \\ -12 \\ -14 \\ -16 \\ -18 \\ -20 \end{array}$	7575051 Lir Var 351 382 1369 2293 3473 4909 6601 8549 10753 13213 13213	$\begin{array}{c} 17154948 \\ \textbf{near Prop} \\ \hline M_{sun} \\ \hline Cnf \\ 1790 \\ 1977 \\ 6599 \\ 9945 \\ 13867 \\ 18365 \\ 23439 \\ 29089 \\ 35315 \\ 42117 \\ 49495 \end{array}$	$\begin{array}{c} 403.0 \mathrm{s} \\ \hline T^{sol} \\ 0.6 \mathrm{s} \\ 0.7 \mathrm{s} \\ 0.7 \mathrm{s} \\ 0.7 \mathrm{s} \\ 1.0 \mathrm{s} \\ 1.2 \mathrm{s} \\ 1.0 \mathrm{s} \\ 1.1 \mathrm{s} \\ 1.3 \mathrm{s} \\ 1.7 \mathrm{s} \end{array}$	539417 Var 351 318 983 1391 1799 2207 2615 3023 3431 3839 4247	$\frac{M_{sim}}{Cnf}$ $\frac{Cnf}{1758}$ $1817$ $5634$ $7754$ $9874$ $11994$ $14114$ $16234$ $18354$ $20474$ $22594$	$\begin{array}{c} T^{sol} \\ 0.1s \\ 0.1s \\ 0.1s \\ 0.1s \\ 0.2s \\ 0.3s \\ 0.4s \\ 0.4s \\ 0.7s \\ 0.8s \\ 0.6s \\ \end{array}$		
Round 1 2 3 4 5 6 7 8 9 10 11 12	$\begin{array}{c} \log_2 Cor_{opt} \\ -1 \\ -2 \\ -4 \\ -6 \\ -8 \\ -10 \\ -12 \\ -14 \\ -16 \\ -18 \\ -20 \\ -22 \end{array}$	$\begin{array}{c} 7575051\\ \hline \\ Var\\ 351\\ 382\\ 1369\\ 2293\\ 3473\\ 4909\\ 6601\\ 8549\\ 10753\\ 13213\\ 15929\\ 18901 \end{array}$	$\begin{array}{c} 17154948 \\ \textbf{near Prop} \\ \hline M_{sun} \\ \hline Cnf \\ 1790 \\ 1977 \\ 6599 \\ 9945 \\ 13867 \\ 18365 \\ 23439 \\ 29089 \\ 35315 \\ 42117 \\ 49495 \\ 57449 \end{array}$	$\begin{array}{c} 403.0 \mathrm{s} \\ \hline \\ 0 \\$	539417 Var 351 318 983 1391 1799 2207 2615 3023 3431 3839 4247 4655	$\frac{M_{sim}}{Cnf}$ $\frac{Cnf}{1758}$ $1817$ $5634$ $7754$ $9874$ $11994$ $14114$ $16234$ $18354$ $20474$ $22594$ $24714$	$\begin{array}{c} T^{sol} \\ 0.1s \\ 0.1s \\ 0.1s \\ 0.2s \\ 0.2s \\ 0.4s \\ 0.4s \\ 0.7s \\ 0.8s \\ 0.6s \\ 1.1s \end{array}$		
Round 1 2 3 4 5 6 7 8 9 10 11 12 13	$\begin{array}{c} \log_2 Cor_{opt} \\ -1 \\ -2 \\ -4 \\ -6 \\ -8 \\ -10 \\ -12 \\ -14 \\ -16 \\ -18 \\ -20 \\ -22 \\ -24 \end{array}$	7575051 Lir 351 382 1369 2293 3473 4909 6601 8549 10753 13213 15929 18901 22129	$\begin{array}{c} 17154948\\ \textbf{near Prop}\\ \hline M_{sun} \\ \hline Cnf \\ 1790 \\ 1977 \\ 6599 \\ 9945 \\ 13867 \\ 18365 \\ 23439 \\ 29089 \\ 35315 \\ 42117 \\ 49495 \\ 57449 \\ 65979 \end{array}$	$\begin{array}{c} 403.0 \mathrm{s} \\ \hline \\ 0 \\$	$\frac{Var}{351}\\\frac{Var}{351}\\\frac{318}{983}\\\frac{1391}{1799}\\\frac{2207}{2615}\\\frac{3023}{3431}\\\frac{3431}{3839}\\\frac{4247}{4655}\\5063$	$\frac{M_{sim}}{Cnf}$ $\frac{Cnf}{1758}$ $\frac{11758}{1817}$ $\frac{5634}{7754}$ $\frac{7754}{9874}$ $\frac{11994}{14114}$ $\frac{16234}{18354}$ $\frac{20474}{22594}$ $\frac{22594}{224714}$ $\frac{24714}{26834}$	$\begin{array}{c} T^{sol} \\ 0.1s \\ 0.1s \\ 0.1s \\ 0.2s \\ 0.2s \\ 0.4s \\ 0.4s \\ 0.7s \\ 0.8s \\ 0.6s \\ 1.1s \\ 0.8s \end{array}$		
Round 1 2 3 4 5 6 7 8 9 10 11 12 13 14	$\begin{array}{c} \log_2 Cor_{opt} \\ -1 \\ -2 \\ -4 \\ -6 \\ -8 \\ -10 \\ -12 \\ -14 \\ -16 \\ -18 \\ -20 \\ -22 \\ -24 \\ -26 \end{array}$	7575051 Lir Var 351 382 1369 2293 3473 4909 6601 8549 10753 13213 15929 18901 22129 225613	$\begin{array}{c} 17154948\\ \textbf{near Prop}\\ \hline M_{sun} \\ \hline Cnf\\ 1790\\ 1977\\ 6599\\ 9945\\ 13867\\ 18365\\ 23439\\ 29089\\ 35315\\ 42117\\ 49495\\ 57449\\ 65979\\ 75085\\ \end{array}$	$\begin{array}{c} 403.0 \text{s} \\ \hline \\ \textbf{perty} \\ \hline \\ T^{sol} \\ 0.6 \text{s} \\ 0.7 \text{s} \\ 0.7 \text{s} \\ 0.7 \text{s} \\ 1.0 \text{s} \\ 1.2 \text{s} \\ 1.0 \text{s} \\ 1.1 \text{s} \\ 1.3 \text{s} \\ 1.7 \text{s} \\ 2.1 \text{s} \\ 2.2 \text{s} \\ 2.5 \text{s} \end{array}$	$539417\\ \hline Var\\ 351\\ 318\\ 983\\ 1391\\ 1799\\ 2207\\ 2615\\ 3023\\ 3431\\ 3839\\ 4247\\ 4655\\ 5063\\ 5471$	$\frac{M_{sim}}{Cnf}$ $\frac{1758}{1758}$ $\frac{1817}{5634}$ $\frac{7754}{7754}$ $\frac{9874}{11994}$ $\frac{11114}{16234}$ $\frac{14114}{16234}$ $\frac{143154}{225944}$ $\frac{24714}{24714}$ $\frac{26834}{28954}$	$\begin{array}{c} T^{sol} \\ 0.1s \\ 0.1s \\ 0.1s \\ 0.2s \\ 0.3s \\ 0.4s \\ 0.4s \\ 0.7s \\ 0.8s \\ 0.6s \\ 1.1s \\ 0.8s \\ 0.9s \\ \end{array}$		
$\begin{array}{c} \text{Round} \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \\ 9 \\ 10 \\ 11 \\ 12 \\ 13 \\ 14 \\ 15 \\ \end{array}$	$\begin{array}{c} \log_2 Cor_{opt} \\ -1 \\ -2 \\ -4 \\ -6 \\ -8 \\ -10 \\ -12 \\ -14 \\ -16 \\ -18 \\ -20 \\ -22 \\ -22 \\ -24 \\ -26 \\ -28 \end{array}$	7575051 Lir Var 351 382 1369 2293 3473 4909 6601 8549 10753 13213 15929 18901 22129 22129 225613 29353	$\begin{array}{c} 17154948 \\ \hline \textbf{near Prop} \\ \hline M_{sun} \\ \hline Cnf \\ 1790 \\ 1977 \\ \hline 6599 \\ 9945 \\ 13867 \\ 13865 \\ 23439 \\ 29089 \\ 35315 \\ 42117 \\ 49495 \\ 57449 \\ 65979 \\ 75085 \\ 84767 \end{array}$	$\begin{array}{c} 403.0 \text{s} \\ \hline \\ \textbf{perty} \\ \hline \\ T^{sol} \\ 0.6 \text{s} \\ 0.7 \text{s} \\ 0.7 \text{s} \\ 0.7 \text{s} \\ 1.0 \text{s} \\ 1.2 \text{s} \\ 1.2 \text{s} \\ 1.3 \text{s} \\ 1.7 \text{s} \\ 2.1 \text{s} \\ 2.2 \text{s} \\ 2.5 \text{s} \\ 2.8 \text{s} \end{array}$	$539417\\ \hline Var\\ 351\\ 318\\ 983\\ 1391\\ 1799\\ 2007\\ 2615\\ 3023\\ 3431\\ 3839\\ 4247\\ 4655\\ 5063\\ 5471\\ 5879$	$\frac{M_{sim}}{Cnf}$ $\frac{N_{sim}}{1758}$ $\frac{11758}{1817}$ $\frac{5634}{7754}$ $\frac{9874}{11994}$ $\frac{14114}{16234}$ $\frac{14114}{16234}$ $\frac{14354}{20474}$ $\frac{20474}{22634}$ $\frac{228954}{31074}$	$\begin{array}{c} T^{sol} \\ 0.1s \\ 0.1s \\ 0.1s \\ 0.2s \\ 0.3s \\ 0.4s \\ 0.4s \\ 0.7s \\ 0.8s \\ 0.8s \\ 1.1s \\ 0.8s \\ 0.9s \\ 1.1s \\ 0.8s \\ 0.9s \\ 1.1s \\ 0.8s \\ 0.9s \\$		
$\begin{array}{c} \text{Round} \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \\ 9 \\ 10 \\ 11 \\ 12 \\ 13 \\ 14 \\ 15 \\ 16 \\ \end{array}$	$\begin{array}{c} \log_2 Cor_{opt} \\ -1 \\ -2 \\ -4 \\ -6 \\ -8 \\ -10 \\ -12 \\ -14 \\ -16 \\ -18 \\ -20 \\ -22 \\ -24 \\ -26 \\ -28 \\ -30 \\ \end{array}$	7575051 Lir Var 351 382 1369 2293 3473 4909 6601 8549 10753 13213 13213 13213 13223 13213 13223 13202 18901 22129 25613 29353 33349	$\begin{array}{c} 17154948 \\ \textbf{near Prop} \\ \hline M_{sun} \\ \hline Cnf \\ 1790 \\ 1977 \\ 6599 \\ 9945 \\ 13867 \\ 18365 \\ 23439 \\ 29089 \\ 35315 \\ 42117 \\ 49495 \\ 57449 \\ 65979 \\ 75085 \\ 84767 \\ 95025 \end{array}$	$\begin{array}{c} 403.0 \mathrm{s} \\ \hline \\ T^{sol} \\ 0.6 \mathrm{s} \\ 0.7 \mathrm{s} \\ 0.7 \mathrm{s} \\ 0.7 \mathrm{s} \\ 1.0 \mathrm{s} \\ 1.2 \mathrm{s} \\ 1.0 \mathrm{s} \\ 1.3 \mathrm{s} \\ 1.3 \mathrm{s} \\ 1.7 \mathrm{s} \\ 2.1 \mathrm{s} \\ 2.1 \mathrm{s} \\ 2.5 \mathrm{s} \\ 2.8 \mathrm{s} \\ 2.7 \mathrm{s} \end{array}$	$\begin{array}{c} 539417\\ \hline\\ Var\\ 351\\ 318\\ 983\\ 1391\\ 1799\\ 2207\\ 2615\\ 3023\\ 3431\\ 3839\\ 4247\\ 4655\\ 5063\\ 5471\\ 5879\\ 6287\\ \end{array}$	$\frac{M_{sim}}{Cnf}$ $\frac{Cnf}{1758}$ $1817$ $5634$ $7754$ $11994$ $14114$ $16234$ $18354$ $20474$ $22594$ $24714$ $22594$ $24714$ $28954$ $31074$ $33194$	$\begin{array}{c} T^{sol} \\ 0.1s \\ 0.1s \\ 0.1s \\ 0.2s \\ 0.4s \\ 0.4s \\ 0.4s \\ 0.6s \\ 1.1s \\ 0.8s \\ 0.8s \\ 1.1s \\ 1.6s \\ \end{array}$		
$\begin{array}{c} \text{Round} \\ \hline 1 \\ \hline 2 \\ \hline 3 \\ \hline 4 \\ \hline 5 \\ \hline 6 \\ \hline 7 \\ \hline 8 \\ 9 \\ \hline 10 \\ 11 \\ 12 \\ \hline 13 \\ 14 \\ \hline 15 \\ 16 \\ \hline 17 \\ \end{array}$	$\begin{array}{c} \log_2 Cor_{opt} \\ \hline -1 \\ -2 \\ -4 \\ -6 \\ -8 \\ -10 \\ -12 \\ -14 \\ -16 \\ -18 \\ -20 \\ -22 \\ -24 \\ -26 \\ -28 \\ -30 \\ -32 \\ \end{array}$	7575051 Lir 351 382 1369 2293 3473 4909 6601 8549 10753 13213 13213 15929 18901 22129 25613 29353 33349 37601	$\begin{array}{c} 17154948 \\ \hline \textbf{near Prop} \\ \hline M_{sun} \\ \hline Cnf \\ 1790 \\ 1977 \\ 6599 \\ 9945 \\ 13867 \\ 13865 \\ 23439 \\ 29089 \\ 35315 \\ 42117 \\ 49495 \\ 57449 \\ 65979 \\ 75085 \\ 84767 \\ 95025 \\ 105859 \end{array}$	$\begin{array}{c} 403.0 \mathrm{s} \\ \hline \\ 0 \\$	$\begin{array}{c} 539417\\ \hline\\ Var\\ 351\\ 318\\ 983\\ 1391\\ 1799\\ 2207\\ 2615\\ 3023\\ 3431\\ 3839\\ 4247\\ 4655\\ 5063\\ 5471\\ 5879\\ 6287\\ 6695\\ \end{array}$	$\frac{M_{sim}}{Cnf}$ $\frac{Cnf}{1758}$ $1817$ $5634$ $7754$ $11994$ $14114$ $16234$ $18354$ $20474$ $22594$ $24714$ $22594$ $24714$ $22594$ $24714$ $26834$ $20554$ $31074$ $33194$	$\begin{array}{c} 147.3\\ \hline T^{sol}\\ 0.1s\\ 0.1s\\ 0.1s\\ 0.1s\\ 0.2s\\ 0.4s\\ 0.4s\\ 0.6s\\ 1.1s\\ 0.8s\\ 0.9s\\ 1.1s\\ 1.6s\\ 1.9s\\ \end{array}$		
$\begin{array}{c} \text{Round} \\ \hline 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \\ 9 \\ 10 \\ 11 \\ 12 \\ 13 \\ 14 \\ 15 \\ 16 \\ 17 \\ 18 \\ \end{array}$	$\begin{array}{c} \log_2 Cor_{opt} \\ \hline -1 \\ -2 \\ -4 \\ -6 \\ -8 \\ -10 \\ -12 \\ -14 \\ -16 \\ -18 \\ -20 \\ -22 \\ -24 \\ -26 \\ -28 \\ -30 \\ -32 \\ -34 \\ \end{array}$	$\begin{array}{c} 7575051\\ \hline \\ Var\\ 351\\ 382\\ 1369\\ 2293\\ 3473\\ 4909\\ 6601\\ 8549\\ 10753\\ 13213\\ 15929\\ 18901\\ 22129\\ 18901\\ 22129\\ 15923\\ 33349\\ 33349\\ 37601\\ 42109\\ \end{array}$	$\begin{array}{c} 17154948\\ \textbf{near Prop}\\ \hline M_{sun} & Cnf\\ 1790\\ 1977\\ 6599\\ 9945\\ 13867\\ 18365\\ 23439\\ 29089\\ 35315\\ 42117\\ 49495\\ 57449\\ 65979\\ 75085\\ 84767\\ 95025\\ 105859\\ 117269\\ \end{array}$	$\begin{array}{c} 403.0 \mathrm{s} \\ \hline \\ 7^{sol} \\ 0.6 \mathrm{s} \\ 0.7 \mathrm{s} \\ 0.7 \mathrm{s} \\ 0.7 \mathrm{s} \\ 0.7 \mathrm{s} \\ 1.0 \mathrm{s} \\ 1.2 \mathrm{s} \\ 1.0 \mathrm{s} \\ 1.1 \mathrm{s} \\ 1.3 \mathrm{s} \\ 1.7 \mathrm{s} \\ 2.1 \mathrm{s} \\ 2.7 \mathrm{s} \\ 2.7 \mathrm{s} \\ 2.7 \mathrm{s} \\ 5.0 \mathrm{s} \\ 5.0 \mathrm{s} \\ 3.5 \mathrm{s} \end{array}$	$\begin{array}{c} 539417\\ \hline\\ Var\\ 351\\ 318\\ 983\\ 1391\\ 1799\\ 2207\\ 2615\\ 3023\\ 3431\\ 3839\\ 4247\\ 4655\\ 5063\\ 5471\\ 5879\\ 6287\\ 5063\\ 5471\\ 5879\\ 6285\\ 7103\\ \end{array}$	$\frac{M_{sim}}{Cnf}$ $\frac{Cnf}{1758}$ $\frac{11758}{1817}$ $\frac{5634}{7754}$ $\frac{7754}{9874}$ $\frac{11994}{14114}$ $\frac{16234}{18354}$ $\frac{20594}{22594}$ $\frac{24714}{228954}$ $\frac{228954}{33194}$ $\frac{35314}{35314}$ $\frac{35314}{35434}$	$\begin{array}{c} 147.3\\ \hline T^{sol}\\ 0.1s\\ 0.1s\\ 0.1s\\ 0.2s\\ 0.3s\\ 0.4s\\ 0.4s\\ 0.6s\\ 1.1s\\ 0.6s\\ 1.1s\\ 0.6s\\ 1.1s\\ 0.8s\\ 0.9s\\ 1.1s\\ 0.2s\\ 0.2s\\ 0.4s\\ 0.2s\\ 0.2s\\$		
$\begin{array}{c} \text{Round} \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \\ 9 \\ 10 \\ 11 \\ 12 \\ 13 \\ 14 \\ 15 \\ 16 \\ 17 \\ 18 \\ 19 \\ \end{array}$	$\begin{array}{c} \\ \log_2 Cor_{opt} \\ -1 \\ -2 \\ -4 \\ -6 \\ -8 \\ -10 \\ -12 \\ -14 \\ -16 \\ -18 \\ -20 \\ -22 \\ -24 \\ -26 \\ -28 \\ -30 \\ -32 \\ -34 \\ -36 \\ \end{array}$	7575051 Lir Var 351 382 1369 2293 3473 4909 6601 8549 10753 13213 15929 18801 22129 25613 29353 33349 37601 42109 46873	$\begin{array}{c} 17154948\\ \textbf{near Prop}\\ \hline M_{sun} \\ \hline Cnf\\ 1790\\ 1977\\ 6599\\ 9945\\ 13867\\ 18365\\ 23439\\ 29089\\ 35315\\ 42117\\ 49495\\ 557449\\ 65979\\ 75085\\ 84767\\ 95025\\ 105859\\ 117269\\ 129255\\ \end{array}$	$\begin{array}{c} 403.0 \mathrm{s} \\ \hline \\ \mathbf{y} \\$	$\begin{array}{c} 539417\\ \hline\\ Var\\ 351\\ 318\\ 983\\ 1391\\ 1799\\ 2207\\ 2615\\ 3023\\ 3431\\ 3839\\ 4247\\ 3639\\ 4247\\ 55063\\ 5471\\ 5879\\ 6287\\ 6695\\ 5471\\ 5879\\ 6287\\ 7103\\ 7511\\ \end{array}$	$\frac{M_{sim}}{Cnf}$ $\frac{Cnf}{1758}$ $\frac{11758}{1817}$ $\frac{5634}{7754}$ $\frac{7754}{9874}$ $\frac{11994}{14114}$ $\frac{16234}{18354}$ $\frac{20474}{225944}$ $\frac{24714}{24714}$ $\frac{24714}{26834}$ $\frac{24714}{31944}$ $\frac{3194}{35314}$ $\frac{37434}{39554}$	$\begin{array}{c} 147.3 \\ \hline \\ T^{sol} \\ 0.1 \\ s \\ 0.4 \\ 0$		
$\begin{array}{c} \text{Round} \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \\ 9 \\ 10 \\ 11 \\ 12 \\ 13 \\ 14 \\ 15 \\ 16 \\ 17 \\ 18 \\ 19 \\ 20 \\ \end{array}$	$\begin{array}{c} \\ \log_2 Cor_{opt} \\ -1 \\ -2 \\ -4 \\ -6 \\ -8 \\ -10 \\ -12 \\ -14 \\ -16 \\ -18 \\ -20 \\ -22 \\ -24 \\ -26 \\ -28 \\ -30 \\ -32 \\ -32 \\ -34 \\ -36 \\ -38 \\ \end{array}$	7575051 Lir Var 351 382 1369 2293 3473 4909 6601 8549 10753 13213 15929 18901 22129 25613 29353 33349 37601 42109 46873 51893	$\begin{array}{c} 17154948\\ \textbf{near Prop}\\ \hline M_{sun} \\ \hline Cnf\\ 1790\\ 1977\\ 6599\\ 9945\\ 13867\\ 18365\\ 23439\\ 29089\\ 35315\\ 42117\\ 49495\\ 57449\\ 65979\\ 75085\\ 84767\\ 95025\\ 105859\\ 117269\\ 129255\\ 141817\\ \end{array}$	$\begin{array}{c} 403.0 \mathrm{s} \\ \hline \\ 0 \text{erty} \\ \hline \\ $	$\begin{array}{c} 539417\\ \hline\\ Var\\ 351\\ 318\\ 983\\ 1391\\ 1799\\ 2207\\ 2615\\ 3023\\ 3431\\ 3839\\ 4247\\ 4655\\ 5063\\ 5471\\ 5879\\ 6287\\ 6695\\ 7103\\ 7511\\ 7919\\ \end{array}$	$\frac{M_{sim}}{Cnf}$ $\frac{N_{sim}}{1758}$ $\frac{11758}{1817}$ $\frac{5634}{7754}$ $\frac{9874}{11994}$ $\frac{114114}{16234}$ $\frac{14114}{16234}$ $\frac{14114}{22594}$ $\frac{24714}{24714}$ $\frac{26834}{28954}$ $\frac{31074}{33194}$ $\frac{35314}{39554}$ $\frac{39554}{41674}$	$\begin{array}{c} 147.3 \\ \hline \\ T^{sol} \\ 0.1 \\ s \\ 0.2 \\ s \\ 0.3 \\ s \\ 0.4 \\ 0$		
$\begin{array}{c} \text{Round} \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \\ 9 \\ 10 \\ 11 \\ 12 \\ 13 \\ 14 \\ 15 \\ 16 \\ 17 \\ 18 \\ 19 \\ 20 \\ 21 \\ \end{array}$	$\begin{array}{c} \log_2 Cor_{opt} \\ -1 \\ -2 \\ -4 \\ -6 \\ -8 \\ -10 \\ -12 \\ -14 \\ -16 \\ -18 \\ -20 \\ -22 \\ -24 \\ -26 \\ -28 \\ -30 \\ -32 \\ -34 \\ -36 \\ -38 \\ -40 \\ \end{array}$	7575051 Lir Var 351 382 1369 2293 3473 4909 6601 8549 10753 13213 15929 18901 22129 25613 29353 33349 37601 42109 46873 51893 51893	$\begin{array}{c} 17154948 \\ \textbf{near Prop} \\ \hline M_{sun} \\ \hline Cnf \\ 1790 \\ 1977 \\ 6599 \\ 9945 \\ 13867 \\ 18365 \\ 23439 \\ 29089 \\ 35315 \\ 42117 \\ 49495 \\ 57449 \\ 65979 \\ 75085 \\ 84767 \\ 95025 \\ 105859 \\ 117269 \\ 129255 \\ 141817 \\ 154955 \end{array}$	$\begin{array}{c} 403.0 \mathrm{s} \\ \hline \\ 403.0 \mathrm{s} \\ \hline \\ r \\ solution \\ r \\ r \\ solution \\ r \\ $	$\begin{array}{c} 539417\\ \hline\\ Var\\ 351\\ 318\\ 983\\ 1391\\ 1799\\ 2207\\ 2615\\ 3023\\ 3431\\ 3839\\ 4247\\ 4655\\ 5063\\ 5471\\ 4655\\ 5063\\ 5471\\ 5879\\ 6287\\ 6695\\ 7103\\ 7511\\ 7919\\ 8327\\ \end{array}$	$\begin{array}{c} M_{sim} \\ \hline M_{sim} \\ \hline Cnf \\ 1758 \\ 1817 \\ 5634 \\ 7754 \\ 1994 \\ 14114 \\ 16234 \\ 1994 \\ 14114 \\ 16234 \\ 20474 \\ 22594 \\ 24714 \\ 26834 \\ 204714 \\ 28954 \\ 31074 \\ 33194 \\ 35314 \\ 37434 \\ 395514 \\ 41674 \\ 41674 \\ 43794 \end{array}$	$\begin{array}{c} T^{sol}\\ 0.1s\\ 0.1s\\ 0.2s\\ 0.3s\\ 0.4s\\ 0.7s\\ 0.8s\\ 0.6s\\ 1.1s\\ 0.8s\\ 0.9s\\ 1.1s\\ 1.6s\\ 1.9s\\ 2.1s\\ 1.6s\\ 1.7s\\ 2.2s\\ \end{array}$		
$\begin{array}{c} \text{Round} \\ \hline 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \\ 9 \\ 10 \\ 11 \\ 12 \\ 13 \\ 14 \\ 15 \\ 16 \\ 17 \\ 18 \\ 19 \\ 20 \\ 21 \\ 22 \\ \end{array}$	$\begin{array}{c} \log_2 Cor_{opt} \\ \hline -1 \\ -2 \\ -4 \\ -6 \\ -8 \\ -10 \\ -12 \\ -14 \\ -16 \\ -18 \\ -20 \\ -22 \\ -24 \\ -26 \\ -28 \\ -30 \\ -32 \\ -34 \\ -36 \\ -38 \\ -40 \\ -42 \\ \end{array}$	7575051 Lir Var 351 382 1369 2293 3473 4909 6601 8549 10753 13213 13213 13213 13213 13213 1329 18901 22129 25613 29353 33349 37601 42109 46873 51893 57169 62701	$\begin{array}{c} 17154948 \\ \hline \textbf{near Prop} \\ \hline M_{sun} \\ \hline Cnf \\ 1790 \\ 1977 \\ 6599 \\ 9945 \\ 13867 \\ 13867 \\ 13865 \\ 23439 \\ 29089 \\ 35315 \\ 42117 \\ 49495 \\ 57449 \\ 65979 \\ 75085 \\ 84767 \\ 95025 \\ 105859 \\ 117269 \\ 129255 \\ 141817 \\ 154955 \\ 168669 \\ \end{array}$	$\begin{array}{c} 403.0 \mathrm{s} \\ \hline 403.0 \mathrm{s} \\ \hline r \\ solution \\ \hline 0.6 \mathrm{s} \\ 0.6 \mathrm{s} \\ 0.7 \mathrm{s} \\ 0.7 \mathrm{s} \\ 0.7 \mathrm{s} \\ 0.7 \mathrm{s} \\ 1.0 \mathrm{s} \\ 1.2 \mathrm{s} \\ 1.0 \mathrm{s} \\ 1.2 \mathrm{s} \\ 1.2 \mathrm{s} \\ 2.1 \mathrm{s} \\ 2.1 \mathrm{s} \\ 2.2 \mathrm{s} \\ 2.4 \mathrm{s} \\ 2.7 \mathrm{s} \\ 5.0 \mathrm{s} \\ 3.5 \mathrm{s} \\ 5.3 \mathrm{s} \\ 5.3 \mathrm{s} \\ 5.3 \mathrm{s} \\ 3.4 \mathrm{s} \\ 6.0 \mathrm{s} \end{array}$	$\begin{array}{c} 539417\\ \hline\\ Var\\ 351\\ 318\\ 983\\ 1391\\ 799\\ 2207\\ 2615\\ 3023\\ 3431\\ 3839\\ 4247\\ 4655\\ 5063\\ 5471\\ 5879\\ 6287\\ 6695\\ 7103\\ 7511\\ 7919\\ 8327\\ 8327\\ 8735\\ \end{array}$	$\frac{M_{sim}}{Cnf}$ $\frac{Cnf}{1758}$ $1817$ $5634$ $7754$ $11994$ $14114$ $16234$ $18354$ $20474$ $22594$ $24714$ $22594$ $24714$ $226834$ $20474$ $22594$ $24714$ $26834$ $31074$ $33194$ $35314$ $37434$ $39554$ $41674$ $43794$	$\begin{array}{c} 147.3\\ \hline T^{sol}\\ 0.1s\\ 0.1s\\ 0.1s\\ 0.2s\\ 0.3s\\ 0.4s\\ 0.4s\\ 0.6s\\ 1.1s\\ 0.8s\\ 0.6s\\ 1.1s\\ 1.9s\\ 2.1s\\ 1.6s\\ 1.9s\\ 2.1s\\ 1.7s\\ 2.2s\\ 2.2s\end{array}$		
$\begin{array}{c} \text{Round} \\ \hline 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \\ 9 \\ 10 \\ 11 \\ 12 \\ 13 \\ 14 \\ 15 \\ 16 \\ 17 \\ 18 \\ 19 \\ 20 \\ 21 \\ 22 \\ 23 \\ \end{array}$	$\begin{array}{c} \log_2 Cor_{opt} \\ \hline -1 \\ -2 \\ -4 \\ -6 \\ -8 \\ -10 \\ -12 \\ -14 \\ -16 \\ -18 \\ -20 \\ -22 \\ -24 \\ -26 \\ -28 \\ -30 \\ -32 \\ -34 \\ -36 \\ -38 \\ -40 \\ -42 \\ -44 \\ \end{array}$	7575051 Lir Var 351 382 1369 2293 3473 4909 6601 8549 10753 13213 15929 18901 22129 18901 22129 25613 29353 33349 33349 46873 57169 62701 62701 62701	$\begin{array}{c} 17154948\\ \textbf{near Prop}\\ \hline M_{sun} & Cnf\\ 1790\\ 1977\\ 6599\\ 9945\\ 13867\\ 13865\\ 23439\\ 29089\\ 35315\\ 42117\\ 49495\\ 57449\\ 65979\\ 75085\\ 84767\\ 95025\\ 105859\\ 117269\\ 129255\\ 141817\\ 154955\\ 168669\\ 182959\\ \end{array}$	$\begin{array}{c} 403.0 \mathrm{s} \\ \hline \\ 403.0 \mathrm{s} \\ \hline \\ \mathbf{Derty} \\ \hline \\ \hline \\ \hline \\ 0.6 \mathrm{s} \\ 0.7 \mathrm{s} \\ 0.7 \mathrm{s} \\ 0.7 \mathrm{s} \\ 0.7 \mathrm{s} \\ 1.0 \mathrm{s} \\ 1.2 \mathrm{s} \\ 1.0 \mathrm{s} \\ 1.2 \mathrm{s} \\ 1.2 \mathrm{s} \\ 1.2 \mathrm{s} \\ 2.1 \mathrm{s} \\ 2.1 \mathrm{s} \\ 2.2 \mathrm{s} \\ 2.7 \mathrm{s} \\ 2.7 \mathrm{s} \\ 2.7 \mathrm{s} \\ 5.0 \mathrm{s} \\ 5.3 \mathrm{s} \\ 5.3 \mathrm{s} \\ 5.3 \mathrm{s} \\ 5.4 \mathrm{s} \\ 6.0 \mathrm{s} \\ 6.3 \mathrm{s} \\ \end{array}$	$\begin{array}{c} 539417\\ \hline\\ Var\\ 351\\ 318\\ 983\\ 1391\\ 1799\\ 2207\\ 2615\\ 3023\\ 3431\\ 3839\\ 4247\\ 4655\\ 5063\\ 5471\\ 5879\\ 6695\\ 7103\\ 7511\\ 7919\\ 8227\\ 8735\\ 9143\\ \end{array}$	$\frac{M_{sim}}{Cnf}$ $\frac{Cnf}{1758}$ $1817$ $5634$ $7754$ $9874$ $11994$ $14114$ $16234$ $18354$ $20474$ $22594$ $24714$ $26834$ $22594$ $24714$ $26834$ $22594$ $24714$ $26834$ $31074$ $33194$ $35314$ $37434$ $39554$ $41674$ $43794$ $45914$ $48034$	$\begin{array}{c} 147.3\\ \hline T^{sol}\\ 0.1s\\ 0.1s\\ 0.1s\\ 0.2s\\ 0.3s\\ 0.4s\\ 0.4s\\ 0.4s\\ 0.6s\\ 1.1s\\ 0.6s\\ 1.1s\\ 0.6s\\ 1.1s\\ 0.6s\\ 1.1s\\ 0.4s\\ 0.4s\\$		
$\begin{array}{c} \text{Round} \\ \hline 1 \\ 2 \\ \hline 3 \\ 4 \\ 5 \\ \hline 6 \\ 7 \\ \hline 8 \\ 9 \\ 10 \\ 11 \\ 12 \\ 13 \\ 14 \\ 15 \\ 16 \\ 17 \\ 18 \\ 19 \\ 20 \\ 21 \\ 12 \\ 22 \\ 23 \\ 24 \\ \end{array}$	$\begin{array}{c} \log_2 Cor_{opt} \\ -1 \\ -2 \\ -4 \\ -6 \\ -8 \\ -10 \\ -12 \\ -14 \\ -16 \\ -18 \\ -20 \\ -22 \\ -24 \\ -26 \\ -28 \\ -30 \\ -32 \\ -34 \\ -36 \\ -38 \\ -40 \\ -42 \\ -44 \\ -45 \\ \end{array}$	7575051 Var 351 382 1369 2293 3473 4909 6601 8549 10753 13213 15929 18901 22129 18901 22129 18901 22129 25613 29353 33349 337601 42109 46873 57169 62701 68489 74533	$\begin{array}{c} 17154948\\ \hline \textbf{near Prop}\\ \hline M_{sun} & Cnf\\ 1790\\ 1977\\ 6599\\ 9945\\ 13867\\ 18365\\ 23439\\ 29089\\ 35315\\ 42117\\ 42117\\ 42495\\ 57449\\ 65979\\ 75085\\ 84767\\ 95025\\ 105859\\ 117269\\ 129255\\ 141817\\ 154955\\ 168669\\ 182959\\ 197825\\ \end{array}$	$\begin{array}{c} 403.0 \mathrm{s} \\ \hline 403.0 \mathrm{s} \\ \hline \mathbf{r}^{sol} \\ \hline 0.6 \mathrm{s} \\ 0.7 \mathrm{s} \\ \hline 0.7 \mathrm{s} \\ 0.7 \mathrm{s} \\ 0.7 \mathrm{s} \\ 1.0 \mathrm{s} \\ 1.2 \mathrm{s} \\ 1.0 \mathrm{s} \\ 1.1 \mathrm{s} \\ 1.3 \mathrm{s} \\ 1.7 \mathrm{s} \\ 2.1 \mathrm{s} \\ 2.7 \mathrm{s} \\ 2.7 \mathrm{s} \\ 2.8 \mathrm{s} \\ 2.7 \mathrm{s} \\ 5.0 \mathrm{s} \\ 5.3 \mathrm{s} \\ 5.3 \mathrm{s} \\ 5.5 \mathrm{s} \\ 3.4 \mathrm{s} \\ 6.0 \mathrm{s} \\ 6.3 \mathrm{s} \\ 7.7 \mathrm{s} \end{array}$	$\begin{array}{c} 539417\\ \hline\\ Var\\ 351\\ 318\\ 983\\ 1391\\ 1799\\ 2207\\ 2615\\ 3023\\ 3431\\ 3839\\ 4247\\ 4655\\ 5063\\ 5471\\ 4655\\ 5063\\ 5471\\ 5879\\ 6287\\ 6695\\ 7103\\ 7511\\ 7919\\ 8327\\ 8735\\ 8735\\ 8735\\ 9143\\ 9551\\ \end{array}$	$\frac{M_{sim}}{Cnf}$ $\frac{Cnf}{1758}$ $\frac{11758}{1817}$ $\frac{5634}{7754}$ $\frac{7754}{9874}$ $\frac{11994}{14114}$ $\frac{16234}{18354}$ $\frac{20594}{225944}$ $\frac{24714}{24714}$ $\frac{22594}{28954}$ $\frac{24714}{33194}$ $\frac{35314}{35314}$ $\frac{35314}{35314}$ $\frac{41674}{43794}$ $\frac{48034}{50154}$	$\begin{array}{c} T^{sol}\\ 0.1s\\ 0.1s\\ 0.1s\\ 0.1s\\ 0.2s\\ 0.3s\\ 0.4s\\ 0.7s\\ 0.4s\\ 0.7s\\ 0.8s\\ 0.6s\\ 1.1s\\ 0.6s\\ 1.1s\\ 1.6s\\ 1.1s\\ 1.9s\\ 2.1s\\ 1.6s\\ 1.7s\\ 2.2s\\ 3.0s\\ 3.3s\\ 3.3s\\ \end{array}$		
$\begin{array}{c} \text{Round} \\ \hline 1 \\ 2 \\ \hline 3 \\ 4 \\ 5 \\ \hline 6 \\ 7 \\ \hline 8 \\ 9 \\ 10 \\ 11 \\ 12 \\ 13 \\ 14 \\ 15 \\ 16 \\ 17 \\ 18 \\ 19 \\ 20 \\ 21 \\ 18 \\ 19 \\ 20 \\ 21 \\ 22 \\ 23 \\ 24 \\ 25 \\ \end{array}$	$\begin{array}{c} \\ \log_2 Cor_{opt} \\ -1 \\ -2 \\ -4 \\ -6 \\ -8 \\ -10 \\ -12 \\ -14 \\ -16 \\ -18 \\ -20 \\ -22 \\ -24 \\ -26 \\ -28 \\ -30 \\ -32 \\ -34 \\ -36 \\ -38 \\ -40 \\ -42 \\ -45 \\ -48 \\ \end{array}$	7575051 Lir Var 351 382 1369 2293 3473 4909 6601 8549 10753 13213 15929 18901 22129 25613 29353 33349 37601 42109 46873 51893 57169 62701 68489 74533 80833	$\begin{array}{c} 17154948\\ \textbf{near Prop}\\ \hline M_{sun} & Cnf\\ 1790\\ 1977\\ 6599\\ 9945\\ 13867\\ 18365\\ 23439\\ 29089\\ 35315\\ 42117\\ 49495\\ 557449\\ 65979\\ 75085\\ 84767\\ 95025\\ 105859\\ 117269\\ 129255\\ 141817\\ 154955\\ 168669\\ 182959\\ 197825\\ 213267\\ \end{array}$	$\begin{array}{c} 403.0 \mathrm{s} \\ \hline 403.0 \mathrm{s} \\ \hline \mathbf{perty} \\ \hline \\ $	$\begin{array}{c} 539417\\ \hline\\ Var\\ 351\\ \hline\\ 318\\ 983\\ 1391\\ 1799\\ 2207\\ 2615\\ \hline\\ 3023\\ 3431\\ \hline\\ 3839\\ 4247\\ \hline\\ 3839\\ 4247\\ \hline\\ 5879\\ 6287\\ \hline\\ 6095\\ \hline\\ 5471\\ \hline\\ 5879\\ 6287\\ \hline\\ 6095\\ \hline\\ 7103\\ \hline\\ 7511\\ \hline\\ 7919\\ \hline\\ 8327\\ \hline\\ 8735\\ 9143\\ \hline\\ 9959\end{array}$	$\frac{M_{sim}}{Cnf}$ $\frac{N_{sim}}{1758}$ $\frac{11758}{1817}$ $\frac{5634}{7754}$ $\frac{7754}{9874}$ $\frac{11994}{14114}$ $\frac{16234}{18354}$ $\frac{20474}{22594}$ $\frac{24714}{24714}$ $\frac{24714}{24714}$ $\frac{24714}{24714}$ $\frac{24714}{3194}$ $\frac{31074}{35314}$ $\frac{37434}{37434}$ $\frac{45014}{48014}$ $\frac{48014}{50154}$ $\frac{52274}{52274}$	$\begin{array}{c} 147.3 \\ \hline \\ T^{sol} \\ 0.1 \\ 0.1 \\ 0.1 \\ 0.1 \\ 0.1 \\ 0.2 \\ 0.3 \\ 0.4 \\ 0.3 \\ 0.4 \\ 0.3 \\ 0.4 \\ 0.3 \\ 0.4 \\ 0.3 \\ 0.4 \\ 0.3 \\ 0.4 \\ 0.3 \\ 0.4 \\ 0.3 \\ 0.4 \\ 0.3 \\ 0.4 \\ 0$		
$\begin{array}{c} \text{Round} \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \\ 9 \\ 10 \\ 11 \\ 12 \\ 13 \\ 14 \\ 15 \\ 16 \\ 17 \\ 18 \\ 19 \\ 20 \\ 21 \\ 22 \\ 23 \\ 24 \\ 25 \\ 26 \\ \end{array}$	$\begin{array}{c} \log_2 Cor_{opt} \\ -1 \\ -2 \\ -4 \\ -6 \\ -8 \\ -10 \\ -12 \\ -14 \\ -16 \\ -18 \\ -20 \\ -22 \\ -24 \\ -26 \\ -28 \\ -30 \\ -32 \\ -34 \\ -36 \\ -38 \\ -40 \\ -42 \\ -44 \\ -45 \\ -48 \\ -50 \\ \end{array}$	7575051 Lir Var 351 382 1369 2293 3473 4909 6601 8549 10753 13213 15929 18901 22163 33349 37601 42109 46873 33349 37601 42109 46833 51893 51893 57169 62701 68489 74533 80833 87389	$\begin{array}{c} 17154948\\ \hline \textbf{near Prop}\\ \hline M_{sun} & Cnf\\ \hline 1790\\ 1977\\ \hline 6599\\ 9945\\ 13867\\ 18365\\ 23439\\ 29089\\ 35315\\ 42117\\ 49495\\ 57449\\ 65979\\ 75085\\ 84767\\ 95025\\ 105859\\ 117269\\ 129255\\ 105859\\ 117269\\ 129255\\ 141817\\ 154955\\ 168669\\ 182959\\ 197825\\ 213267\\ 229285\\ \end{array}$	$\begin{array}{c} 403.0 \mathrm{s} \\ \hline 403.0 \mathrm{s} \\ \hline \\ \hline \\ T^{sol} \\ \hline 0.6 \mathrm{s} \\ 0.7 \mathrm{s} \\ \hline 0.7 \mathrm{s} \\ 0.7 \mathrm{s} \\ \hline 0.7 \mathrm{s} \\ 1.0 \mathrm{s} \\ 1.2 \mathrm{s} \\ 1.0 \mathrm{s} \\ 1.2 \mathrm{s} \\ 1.2 \mathrm{s} \\ 2.1 \mathrm{s} \\ 2.1 \mathrm{s} \\ 2.1 \mathrm{s} \\ 2.2 \mathrm{s} \\ 2.7 \mathrm{s} \\ 5.0 \mathrm{s} \\ 3.5 \mathrm{s} \\ 5.5 \mathrm{s} \\ 3.4 \mathrm{s} \\ 6.0 \mathrm{s} \\ 6.0 \mathrm{s} \\ 6.3 \mathrm{s} \\ 7.7 \mathrm{s} \\ 8.0 \mathrm{s} \\ 8.8 \mathrm{s} \\ \end{array}$	$\begin{array}{c} 539417\\ \hline\\ Var\\ 351\\ 318\\ 983\\ 1391\\ 1799\\ 2207\\ 2615\\ 3023\\ 3431\\ 3839\\ 4247\\ 4655\\ 5063\\ 5471\\ 4655\\ 5063\\ 5471\\ 5879\\ 6287\\ 6695\\ 7103\\ 7511\\ 5879\\ 6287\\ 6695\\ 7103\\ 7511\\ 8327\\ 8735\\ 9143\\ 9959\\ 9059\\ 10367\\ \end{array}$	$\begin{array}{c} M_{sim} \\ \hline Cnf \\ 1758 \\ 1817 \\ 5634 \\ 7754 \\ 1994 \\ 14114 \\ 16234 \\ 1994 \\ 14114 \\ 16234 \\ 20474 \\ 22594 \\ 24714 \\ 26834 \\ 204714 \\ 26834 \\ 31074 \\ 33194 \\ 35314 \\ 37434 \\ 395514 \\ 41674 \\ 41674 \\ 43794 \\ 45914 \\ 48034 \\ 50154 \\ 52274 \\ 54394 \\ \end{array}$	$\begin{array}{c} 147.3\\ \hline T^{sol}\\ 0.1s\\ 0.1s\\ 0.2s\\ 0.3s\\ 0.4s\\ 0.7s\\ 0.8s\\ 0.6s\\ 1.1s\\ 0.8s\\ 0.6s\\ 1.1s\\ 1.6s\\ 1.9s\\ 2.2s\\ 2.2s\\ 3.0s\\ 3.3s\\ 3.6s\\ 3.7s\\ \end{array}$		
$\begin{array}{c} \text{Round} \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \\ 9 \\ 10 \\ 11 \\ 12 \\ 13 \\ 14 \\ 15 \\ 16 \\ 17 \\ 18 \\ 19 \\ 20 \\ 21 \\ 18 \\ 19 \\ 20 \\ 21 \\ 22 \\ 23 \\ 24 \\ 25 \end{array}$	$\begin{array}{c} \\ \log_2 Cor_{opt} \\ -1 \\ -2 \\ -4 \\ -6 \\ -8 \\ -10 \\ -12 \\ -14 \\ -16 \\ -18 \\ -20 \\ -22 \\ -24 \\ -26 \\ -28 \\ -30 \\ -32 \\ -34 \\ -36 \\ -38 \\ -40 \\ -42 \\ -45 \\ -48 \\ \end{array}$	7575051 Lir Var 351 382 1369 2293 3473 4909 6601 8549 10753 13213 15929 18901 22129 25613 29353 33349 37601 42109 46873 51893 57169 62701 68489 74533 80833	$\begin{array}{c} 17154948\\ \textbf{near Prop}\\ \hline M_{sun} & Cnf\\ 1790\\ 1977\\ 6599\\ 9945\\ 13867\\ 18365\\ 23439\\ 29089\\ 35315\\ 42117\\ 49495\\ 557449\\ 65979\\ 75085\\ 84767\\ 95025\\ 105859\\ 117269\\ 129255\\ 141817\\ 154955\\ 168669\\ 182959\\ 197825\\ 213267\\ \end{array}$	$\begin{array}{c} 403.0 \mathrm{s} \\ \hline 403.0 \mathrm{s} \\ \hline \mathbf{perty} \\ \hline \\ $	$\begin{array}{c} 539417\\ \hline\\ Var\\ 351\\ \hline\\ 318\\ 983\\ 1391\\ 1799\\ 2207\\ 2615\\ \hline\\ 3023\\ 3431\\ \hline\\ 3839\\ 4247\\ \hline\\ 3839\\ 4247\\ \hline\\ 5879\\ 6287\\ \hline\\ 6095\\ \hline\\ 5471\\ \hline\\ 5879\\ 6287\\ \hline\\ 6095\\ \hline\\ 7103\\ \hline\\ 7511\\ \hline\\ 7919\\ \hline\\ 8327\\ \hline\\ 8735\\ 9143\\ \hline\\ 9959\end{array}$	$\frac{M_{sim}}{Cnf}$ $\frac{N_{sim}}{1758}$ $\frac{11758}{1817}$ $\frac{5634}{7754}$ $\frac{7754}{9874}$ $\frac{11994}{14114}$ $\frac{16234}{18354}$ $\frac{20474}{22594}$ $\frac{24714}{24714}$ $\frac{24714}{24714}$ $\frac{24714}{24714}$ $\frac{24714}{3194}$ $\frac{31074}{35314}$ $\frac{37434}{37434}$ $\frac{45014}{48014}$ $\frac{48014}{50154}$ $\frac{52274}{52274}$	$\begin{array}{c} 147.3;\\ \hline \\ T^{sol}\\ 0.1s\\ 0.1s\\ 0.1s\\ 0.1s\\ 0.2s\\ 0.3s\\ 0.4s\\ 0.3s\\ 0.4s\\ 0.3s\\ 0.4s\\ 0.$		

-54

-56

-58 -60

28

29

30

31Total 101269

5.1s

263049 8.5s 11183 58634

 Table 4. Experimental results of PRESENT

	Differential Property									
D 1	1 D		M <sub>sun</sub>			$M_{sim}$				
Round	$\log_2 P_{opt}$	Var	Cnf	$T^{sol}$	Var	Cnf	$T^{sol}$			
1	-2	669	2392	2.9s	667	2339	1.1s			
2	-4	668	2179	0.4s	472	1737	0.3s			
3	-7	2659	8117	0.8s	1491	5486	0.7s			
4	-10	4653	13313	1.2s	2129	7678	0.7s			
5	-14	11193	30351	1.3s	4501	15503	1.1s			
6	-18	16845	43752	1.7s	6085	20039	1.1s			
7	-25	50313	125223	7.6s	18281	55018	5.0s			
8	-31	60335	145130	15.8s	21455	60545	9.9s			
9	-36	63766	150466	18.8s	20654	57228	14.1s			
10	-41	80418	187330	23.0s	23402	64540	16.6s			
11	-46	98990	228226	70.5s	26150	71852	42.8s			
12	-51	119482	273154	103.0s	28898	79164	27.1s			
13	-56	141894	322114	227.8s	31646	86476	52.7s			
14	-61	166226	375106	140.7s	34394	93788	57.1s			
15	-66	192478	432130	256.9s	37142	101100	58.8s			
16	-71	220650	493186	203.8s	39890	108412	75.2s			
17	-76	250742	558274	354.1s	42638	115724	76.6s			
18	-81	282754	627394	242.8s	45386	123036	98.5s			
19	-86	316686	700546	287.3s	48134	130348	132.7s			
20	-91	352538	777730	406.6s	50882	137660	137.9s			
21	-96	390310	858946	479.1s	53630	144972	106.8s			
22	-101	430002	944194	497.5s	56378	152284	111.5s			
23	-106	471614	1033474	335.0s	59126	159596	175.3s			
24	-111	515146	1126786	560.1s	61874	166908	170.5s			
25	-116	560598	1224130	621.7s	64622	174220	324.8s			
Total		4801629	10683643	4860.6s	779927	2135653	1698.9s			
		I	linear Pr	operty						
ъ 1	1 0		$M_{sun}$		M <sub>sim</sub>					
Round	$\log_2 Cor_{opt}$	Var	Cnf	$T^{sol}$	Var Cnf		$T^{sol}$			
1	-1	367	1246	1.6s	351	1214	0.9s			
2	-2	446	1433	0.7s	318	1273	0.4s			
3	-4	1705	4967	1.4s	983	4002	0.7s			
4	-6	2997	7769	1.2s	1391	5578	0.8s			
5	-8	4673	11147	1.3s	1799	7154	0.7s			
6	-10	6733	15101	1.3s	2207	8730	1.0s			
7	-13	14268	30114	3.6s	4252	16115	2.5s			
8	-16	19731	39396	6.6s	5473	19691	4.5s			
9	-19	26058	49926	9.8s	6694	23267	10.8s			
10	-22	33249	61704	20.9s	7915	26843	21.6s			
10		30-10	51.01	-0.05	1.010		-1.00			

 Table 5. Experimental results of RECTANGLE

Round	$\log_2 Cor_{opt}$		$M_{sun}$			$M_{sim}$	
reound	1082 001 opt	Var	Cnf	$T^{sol}$	Var	Cnf	$T^{sol}$
1	-1	367	1246	1.6s	351	1214	0.9s
2	-2	446	1433	0.7s	318	1273	0.4s
3	-4	1705	4967	1.4s	983	4002	0.7s
4	-6	2997	7769	1.2s	1391	5578	0.8s
5	-8	4673	11147	1.3s	1799	7154	0.7s
6	-10	6733	15101	1.3s	2207	8730	1.0s
7	-13	14268	30114	3.6s	4252	16115	2.5s
8	-16	19731	39396	6.6s	5473	19691	4.5s
9	-19	26058	49926	9.8s	6694	23267	10.8s
10	-22	33249	61704	20.9s	7915	26843	21.6s
11	-25	41304	74730	48.2s	9136	30419	44.1s
12	-28	50223	89004	104.5s	10357	33995	74.6s
13	-31	60006	104526	234.6s	11578	37571	220.5s
14	-34	70653	121296	292.6s	12799	41147	271.6s
15	-37	82164	139314	380.6s	14020	44723	429.58
16	-40	94539	158580	1073.8s	15241	48299	778.5s
17	-42	71037	118311	368.5s	10435	33506	205.9s
18	-45	119292	197409	507.8s	16162	52415	875.7s
19	-48	134115	220227	1286.6s	17479	56183	1150.2
20	-51	149802	244293	1312.7s	18796	59951	1081.4
21	-54	166353	269607	1214.7s	20113	63719	1265.1
22	-57	183768	296169	1467.1s	21430	67487	1363.2
23	-60	202047	323979	1781.8s	22747	71255	1745.2
24	-63	221190	353037	1884.8s	24064	75023	1888.6
25	-66	241197	383343	5480.7s	25381	78791	5008.5
Total		1997917	3316628	17487.4s	281121	908351	16446.6

Table 6. Experiment	tal results of GIFT64
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		Diffe	erential F	Propert	У					
	Round $\log_2 P_{ont}$ $M_{sun}$ $M_{sim}$									
Round	$\log_2 P_{opt}$	Var	Cnf	$T^{sol}$	Var	Cnf	$T^{sol}$			
1	-1.415	590	2747	0.3s	590	2699	0.2s			
2	-3.415	1560	6677	0.3s	1268	5947	0.2s			
3	-7	4554	16630	0.5s	2990	12916	0.3s			
4	-11.415	11663	36670	3.2s	6281	24437	0.5s			
5	-17	28744	81820	15.5s	13678	48259	2.4s			
6	-22.415	38950	103956	33.8s	16090	53830	19.4s			
7	-28.415	65899	168535	110.9s	24275	78099	66.7s			
8	-38	136625	334925	433.1s	49795	147570	343.9s			
9	-42	73534	175738	74.6s	23962	69556	25.8s			
10	-48	136911	323127	191.0s	38249	112630	62.1s			
11	-52	110934	259130	33.0s	26634	79812	43.5s			
12	-52	198771	460311	189.2s	42257	128014	54.8s			
13	-62	156014	358650	56.6s	29306	90068	20.7s			
13	-68	272151	621687	70.7s	46265	143398	20.7s			
15	-08	208774	474298	46.8s	40203 31978	143398	5.1s			
15	-72	357051	474298 807255	46.8s 107.8s	28561	86231	38.6s			
10	-78	269214	807255 606074	51.2s	28561	85367	38.6s 13.7s			
17	-82	453471	1017015	51.2s 119.7s	30997	94787	13.7s 56.1s			
18	-88	337334	753978	59.5s	29353	94787 93347	34.6s			
20		561411	1250967		29353					
20	-98 -102			133.5s		103343	59.6s			
21 22	-102 -108	413134	918010 1509111	82.6s 125.7s	$31501 \\ 35869$	101327 111899	16.2s 75.3s			
22		680871 496614		125.7s 87.5s	33649					
	-112		1098170	87.5s 239.1s		109307	35.5s			
24	-118	811851	1791447 1294458		38305	120455	142.2s 40.4s			
25	-122	587774		120.8s	35797	117287				
26	-128	954351	2097975	251.9s	40741	129011	137.8s			
27	-132	686614	1506874	155.6s	37945	125267	11.8s			
00	190	1100971	040000	90F 9-	49177	197507	100.0-			
28 Total	-138	I	2428695 20504930 inear Pro	365.3s 3160.9s perty	43177 800151	137567 2512754	100.2s 1416.4s			
Total		9163735 Li	20504930 inear Pro $M_{sun}$	3160.9s	800151	2512754 M <sub>sim</sub>	1416.4s			
Total Round	$\log_2 Cor_{opt}$	9163735 Li	$\frac{20504930}{\text{inear Pro}}$ $\frac{M_{sun}}{Cnf}$	3160.9s perty T <sup>sol</sup>	800151 Var	$\begin{array}{c} 2512754\\ \hline M_{sim}\\ \hline Cnf \end{array}$	1416.4s $T^{sol}$			
Total Round	log <sub>2</sub> Cor <sub>opt</sub>	9163735 Li <u>Var</u> 351	$\begin{array}{c} 20504930\\ \textbf{inear Pro}\\ \hline M_{sun}\\ \hline Cnf\\ 1150 \end{array}$	3160.9s perty T <sup>sol</sup> 1.1s	800151 Var 351	$\begin{array}{c} 2512754\\ \hline M_{sim}\\ \hline Cnf\\ 1118 \end{array}$	$\frac{1416.4s}{T^{sol}}$			
Total Round 1 2	log <sub>2</sub> Cor <sub>opt</sub> -1 -2	9163735 Li Var 351 382	$\begin{array}{c} 20504930 \\ \text{inear Pro} \\ \hline M_{sun} \\ \hline Cnf \\ 1150 \\ 1337 \end{array}$	3160.9s <b>perty</b> T <sup>sol</sup> 1.1s 0.3s	800151 Var 351 318	$\begin{array}{c} 2512754\\ \hline M_{sim}\\ \hline Cnf\\ 1118\\ 1177\\ \end{array}$	$   \begin{array}{r} 1416.4s \\   \hline         T^{sol} \\         0.8s \\         0.4s \\     \end{array} $			
Total Round 1 2 3	log <sub>2</sub> Cor <sub>opt</sub> -1 -2 -3	9163735 Li Var 351 382 637	$\begin{array}{c} 20504930\\ \text{inear Pro}\\ \hline M_{sun}\\ \hline Cnf\\ 1150\\ 1337\\ 2245 \end{array}$	3160.9s <b>perty</b> <u>T<sup>sol</sup></u> <u>1.1s</u> 0.3s 0.4s	800151 Var 351 318 445	$\begin{array}{c} 2512754\\ \hline M_{sim}\\ \hline Cnf\\ 1118\\ 1177\\ 1765\\ \end{array}$	$     \begin{array}{r} 1416.4s \\     \hline         T^{sol} \\         0.8s \\         0.4s \\         0.4s \\         \end{array} $			
Total Round 1 2 3 4	log <sub>2</sub> Cor <sub>opt</sub> -1 -2 -3 -5	9163735 Li Var 351 382 637 2039	$\begin{array}{c} 20504930\\ \textbf{mear Pro}\\ \hline M_{sun}\\ \hline Cnf\\ 1150\\ 1337\\ 2245\\ \hline 6879\\ \end{array}$	3160.9s perty T <sup>sol</sup> 1.1s 0.3s 0.4s 0.8s	800151 Var 351 318 445 1269	$\begin{array}{c} M_{sim} \\ \hline \\ Cnf \\ 1118 \\ 1177 \\ 1765 \\ 4954 \end{array}$	$     \begin{array}{r} 1416.4s \\     \hline       T^{sol} \\       0.8s \\       0.4s \\       0.4s \\       0.7s \\     \end{array} $			
Total Round 1 2 3 4 5	$log_2 Cor_{opt}$ -1 -2 -3 -5 -7	9163735 Li Var 351 382 637 2039 3155	$\begin{array}{c} 20504930\\ \hline {\bf mear\ Prc}\\ \hline M_{sun}\\ \hline Cnf\\ 1150\\ 1337\\ 2245\\ \hline 6879\\ 10033\\ \end{array}$	$\begin{array}{c} 3160.9 \text{s} \\ \textbf{perty} \\ \hline \\ T^{sol} \\ 1.1 \text{s} \\ 0.3 \text{s} \\ 0.4 \text{s} \\ 0.8 \text{s} \\ 0.8 \text{s} \end{array}$	800151 Var 351 318 445 1269 1741	$\begin{array}{c} \\ \underline{M_{sim}} \\ \underline{Cnf} \\ 1118 \\ 1177 \\ 1765 \\ 4954 \\ 6562 \end{array}$	$   \begin{array}{r} 1416.4s \\   \hline         T^{sol} \\         0.8s \\         0.4s \\         0.4s \\         0.7s \\         0.8s \\         \end{array} $			
Total Round 1 2 3 4 5 6	log <sub>2</sub> Cor <sub>opt</sub> -1 -2 -3 -5 -7 -10	9163735 Li Var 351 382 637 2039 3155 7077	$\begin{array}{c} 20504930\\ \hline {\bf mear \ Pro}\\ \hline M_{sun}\\ \hline Cnf\\ 1150\\ 1337\\ 2245\\ 6879\\ 10033\\ 21216\\ \end{array}$	$\begin{array}{c} 3160.9 \text{s} \\ \textbf{perty} \\ \hline T^{sol} \\ 1.1 \text{s} \\ 0.3 \text{s} \\ 0.4 \text{s} \\ 0.8 \text{s} \\ 0.8 \text{s} \\ 1.5 \text{s} \end{array}$	800151 Var 351 318 445 1269 1741 3601	$\begin{array}{c} \\ \underline{M_{sim}} \\ \underline{Cnf} \\ 1118 \\ 1177 \\ 1765 \\ 4954 \\ 6562 \\ 12815 \end{array}$	$\begin{array}{c} 1416.4s\\ \hline T^{sol}\\ 0.8s\\ 0.4s\\ 0.4s\\ 0.7s\\ 0.8s\\ 1.5s\\ \end{array}$			
Total Round 1 2 3 4 5 6 7	log <sub>2</sub> Cor <sub>opt</sub> -1 -2 -3 -5 -7 -10 -13	9163735 Li Var 351 382 637 2039 3155 7077 10236	$\begin{array}{c} 20504930\\ \hline {\bf mear \ Pro}\\ \hline M_{sun}\\ \hline Cnf\\ 1150\\ 1337\\ 2245\\ 6879\\ 10033\\ 21216\\ 29106\\ \end{array}$	$\begin{array}{c} 3160.9 \text{s} \\ \textbf{perty} \\ \hline T^{sol} \\ 1.1 \text{s} \\ 0.3 \text{s} \\ 0.4 \text{s} \\ 0.8 \text{s} \\ 0.8 \text{s} \\ 1.5 \text{s} \\ 2.3 \text{s} \end{array}$	$800151 \\ \hline Var \\ 351 \\ 318 \\ 445 \\ 1269 \\ 1741 \\ 3601 \\ 4822$	$\begin{array}{c} M_{sim} \\ \hline Cnf \\ 1118 \\ 1177 \\ 1765 \\ 4954 \\ 6562 \\ 12815 \\ 16247 \end{array}$	$\begin{array}{c} 1416.4s\\ \hline T^{sol}\\ 0.8s\\ 0.4s\\ 0.7s\\ 0.8s\\ 1.5s\\ 2.2s\\ \end{array}$			
Total Round 1 2 3 4 5 6 7 8	$\begin{array}{c} \log_2 Cor_{opt} \\ -1 \\ -2 \\ -3 \\ -5 \\ -7 \\ -10 \\ -13 \\ -16 \end{array}$	9163735 Li Var 351 382 637 2039 3155 7077 10236 13971	$\begin{array}{c} 20504930\\ \hline {\bf mear Pro}\\ \hline M_{sun}\\ \hline Cnf\\ 1150\\ 1337\\ 2245\\ 6879\\ 10033\\ 21216\\ 29106\\ 38244 \end{array}$	$\begin{array}{c} 3160.9 \text{s} \\ \textbf{perty} \\ \hline T^{sol} \\ 1.1 \text{s} \\ 0.3 \text{s} \\ 0.4 \text{s} \\ 0.8 \text{s} \\ 1.5 \text{s} \\ 2.3 \text{s} \\ 4.5 \text{s} \end{array}$	800151 Var 351 318 445 1269 1741 3601 4822 6043	$\begin{array}{c} M_{sim} \\ \hline Cnf \\ 1118 \\ 1177 \\ 1765 \\ 4954 \\ 6562 \\ 12815 \\ 16247 \\ 19679 \end{array}$	$\begin{array}{c} 1416.4s\\ \hline T^{sol}\\ 0.8s\\ 0.4s\\ 0.7s\\ 0.8s\\ 1.5s\\ 2.2s\\ 3.7s\\ \end{array}$			
Total Round 1 2 3 4 5 6 7 8 9	$\begin{array}{c} \log_2 Cor_{opt} \\ -1 \\ -2 \\ -3 \\ -5 \\ -7 \\ -10 \\ -13 \\ -16 \\ -20 \end{array}$	9163735 <i>Var</i> 351 382 637 2039 3155 7077 10236 13971 24950	$\begin{array}{c} 20504930\\ \hline {\bf mear} ~{\bf Pro}\\ \hline M_{sun}\\ \hline Cnf\\ 1150\\ 1337\\ 2245\\ 6879\\ 10033\\ 21216\\ 29106\\ 38244\\ 65986 \end{array}$	$\begin{array}{c} 3160.9 \text{s} \\ \hline T^{sol} \\ 1.1 \text{s} \\ 0.3 \text{s} \\ 0.4 \text{s} \\ 0.8 \text{s} \\ 1.5 \text{s} \\ 2.3 \text{s} \\ 4.5 \text{s} \\ 27.2 \text{s} \end{array}$	800151 Var 351 318 445 1269 1741 3601 4822 6043 10250	$\begin{array}{c} M_{sim} \\ Cnf \\ 1118 \\ 1177 \\ 1765 \\ 4954 \\ 6562 \\ 12815 \\ 16247 \\ 19679 \\ 31940 \end{array}$	$\begin{array}{c} 1416.4s\\ \hline T^{sol}\\ 0.8s\\ 0.4s\\ 0.4s\\ 0.7s\\ 1.5s\\ 2.2s\\ 3.7s\\ 18.8s \end{array}$			
Total Round 1 2 3 4 5 6 6 7 8 9 9 10	$\begin{array}{c} \log_2 Cor_{opt} \\ -1 \\ -2 \\ -3 \\ -5 \\ -7 \\ -10 \\ -13 \\ -16 \\ -20 \\ -25 \end{array}$	9163735 Li Var 351 382 637 2039 3155 7077 10236 13971 24950 41805	$\begin{array}{c} 20504930\\ \hline {\bf mear Pro}\\ \hline M_{sun}\\ \hline Cnf\\ 1150\\ 1337\\ 2245\\ 6879\\ 10033\\ 21216\\ 29106\\ 38244\\ 65986\\ 106810\\ \end{array}$	$\begin{array}{c} 3160.9 \text{s} \\ \hline T^{sol} \\ \hline 1.1 \text{s} \\ 0.3 \text{s} \\ 0.4 \text{s} \\ 0.8 \text{s} \\ 0.8 \text{s} \\ 1.5 \text{s} \\ 2.3 \text{s} \\ 4.5 \text{s} \\ 27.2 \text{s} \\ 218.3 \text{s} \end{array}$	800151 Var 351 318 445 1269 1741 3601 4822 6043 10250 16955	$\begin{array}{c} M_{sim} \\ \hline \\ Cnf \\ 1118 \\ 1177 \\ 1765 \\ 4954 \\ 6562 \\ 12815 \\ 16247 \\ 19679 \\ 919679 \\ 31940 \\ 49845 \end{array}$	$\begin{array}{c} 1416.4s\\ \hline T^{sol}\\ 0.8s\\ 0.4s\\ 0.4s\\ 0.7s\\ 1.5s\\ 2.2s\\ 3.7s\\ 18.8s\\ 182.2s\\ \end{array}$			
Total Round 1 2 3 4 5 6 6 7 8 9 9 10 11	$\begin{array}{c} \log_2 Cor_{opt} \\ -1 \\ -2 \\ -3 \\ -5 \\ -7 \\ -10 \\ -13 \\ -16 \\ -20 \\ -25 \\ -29 \end{array}$	9163735 Li Var 351 382 637 2039 3155 7077 10236 13971 24950 41805 43090	$\begin{array}{c} 20504930\\ \hline anear Pro\\ M_{sun}\\ Cnf\\ 1150\\ 1337\\ 2245\\ 6879\\ 10033\\ 21216\\ 29106\\ 38244\\ 65986\\ 106810\\ 107342 \end{array}$	$\begin{array}{c} 3160.9 \text{s} \\ \hline \\ \textbf{perty} \\ \hline \\ T^{sol} \\ 1.1 \text{s} \\ 0.3 \text{s} \\ 0.4 \text{s} \\ 0.8 \text{s} \\ 1.5 \text{s} \\ 2.3 \text{s} \\ 4.5 \text{s} \\ 27.2 \text{s} \\ 218.3 \text{s} \\ 592.1 \text{s} \end{array}$	800151 Var 351 318 445 1269 1741 3601 4822 6043 10250 10250 10955 16742	$\begin{array}{c} Simplemetric{2512754}{2512754}\\ \hline M_{sim} & Cnf \\ \hline 1118 \\ 1177 \\ 1765 \\ 4954 \\ 6562 \\ 12815 \\ 16247 \\ 19679 \\ 31940 \\ 49845 \\ 47540 \end{array}$	$\begin{array}{c} 1416.4s\\ \hline T^{sol}\\ 0.8s\\ 0.4s\\ 0.7s\\ 0.8s\\ 1.5s\\ 2.2s\\ 3.7s\\ 18.8s\\ 182.2s\\ 460.1s\\ \end{array}$			
Total Round 1 2 3 4 5 6 7 8 9 10 11 11 12	$\begin{array}{c} \log_2 Cor_{opt} \\ -1 \\ -2 \\ -3 \\ -5 \\ -7 \\ -10 \\ -13 \\ -16 \\ -20 \\ -25 \\ -29 \\ -31 \\ \end{array}$	9163735 Li Var 351 382 637 2039 3155 7077 10236 13971 24950 41805 43090 25795	$\begin{array}{c} 20504930\\ \textbf{mear Pro}\\ \hline M_{sun}\\ \hline Cnf\\ 1150\\ 1337\\ 2245\\ 6879\\ 10033\\ 21216\\ 29106\\ 38244\\ 65986\\ 106810\\ 107342\\ 63539 \end{array}$	$\begin{array}{c} 3160.9 \text{s} \\ \hline \\ \textbf{perty} \\ \hline \\ \hline \\ \textbf{T}^{sol} \\ 1.1 \text{s} \\ 0.3 \text{s} \\ 0.4 \text{s} \\ 0.8 \text{s} \\ 0.8 \text{s} \\ 1.5 \text{s} \\ 2.3 \text{s} \\ 4.5 \text{s} \\ 2.3 \text{s} \\ 4.5 \text{s} \\ 218.3 \text{s} \\ 592.1 \text{s} \\ 592.1 \text{s} \\ 175.1 \text{s} \end{array}$	800151 Var 351 318 445 1269 1741 3601 4822 6043 10250 16955 16742 8893	$\begin{array}{c} 2512754\\ \hline\\ M_{sim}\\ Cnf\\ 1118\\ 1177\\ 1765\\ 4954\\ 6562\\ 12815\\ 16247\\ 19679\\ 31940\\ 49845\\ 47540\\ 25474 \end{array}$	$\begin{array}{c} 1416.4 \\ \hline T^{sol} \\ 0.8 \\ 0.4 \\ 0.7 \\ 0.8 \\ 0.4 \\ 0.7 \\ 0.8 \\ 1.5 \\ 2.2 \\ 8.7 \\ 1.5 \\ 2.2 \\ 3.7 \\ 18.2 \\ 2.5 \\ 182.2 \\ 460.1 \\ 186.5 \\ 166.5 \\ \end{array}$			
Total Round 1 2 3 4 5 6 6 7 8 9 9 10 11 11 12 13	$\begin{array}{c} \log_2 Cor_{opt} \\ -1 \\ -2 \\ -3 \\ -5 \\ -7 \\ -10 \\ -13 \\ -16 \\ -20 \\ -25 \\ -29 \\ -31 \\ -34 \end{array}$	9163735 <i>Var</i> 351 382 637 2039 3155 7077 10236 13971 24950 41805 43090 25795 45021	$\begin{array}{c} 20504930\\ \hline mear \ Pro\\ \hline M_{sun} \\ \hline Cnf \\ 1150 \\ 1337 \\ 2245 \\ 6879 \\ 10033 \\ 21216 \\ 29106 \\ 38244 \\ 65986 \\ 106810 \\ 107342 \\ 63539 \\ 110115 \end{array}$	$\begin{array}{c} 3160.9 \text{s} \\ \hline \textbf{perty} \\ \hline T^{sol} \\ 1.1 \text{s} \\ 0.3 \text{s} \\ 0.4 \text{s} \\ 0.8 \text{s} \\ 0.8 \text{s} \\ 1.5 \text{s} \\ 2.3 \text{s} \\ 4.5 \text{s} \\ 27.2 \text{s} \\ 218.3 \text{s} \\ 592.1 \text{s} \\ 175.1 \text{s} \\ 218.2 \text{s} \end{array}$	800151 Var 351 318 445 1269 1741 3601 4822 6043 10250 16955 16742 8893 13705	$\begin{array}{c} M_{sim} \\ Cnf \\ 1118 \\ 1177 \\ 1765 \\ 4954 \\ 6562 \\ 12815 \\ 16247 \\ 19679 \\ 31940 \\ 49845 \\ 47540 \\ 25474 \\ 39935 \end{array}$	$\begin{array}{c} 1416.4s\\ \hline T^{sol}\\ 0.8s\\ 0.4s\\ 0.7s\\ 0.8s\\ 1.5s\\ 2.2s\\ 3.7s\\ 18.8s\\ 182.2s\\ 460.1s\\ 166.5s\\ 215.0s\end{array}$			
Total Round 1 2 3 4 5 6 7 7 8 9 10 11 11 12 13 14	$\begin{array}{c} \log_2 Cor_{opt} \\ -1 \\ -2 \\ -3 \\ -5 \\ -7 \\ -10 \\ -13 \\ -16 \\ -20 \\ -25 \\ -29 \\ -31 \\ -34 \\ -37 \end{array}$	9163735 <i>Var</i> 351 382 637 2039 3155 7077 10236 13971 24950 41805 43090 25795 45021 52500	$\begin{array}{c} 20504930\\ \hline \textbf{mear Pro}\\ \hline M_{sun}\\ \hline Cnf\\ 1150\\ 1337\\ 2245\\ 6879\\ 10033\\ 21216\\ 29106\\ 38244\\ 65986\\ 106810\\ 107342\\ 65539\\ 110115\\ 127317\\ \end{array}$	$\begin{array}{c} 3160.9 \text{s} \\ \textbf{perty} \\ \hline \\ T^{sol} \\ 1.1 \text{s} \\ 0.3 \text{s} \\ 0.4 \text{s} \\ 0.8 \text{s} \\ 1.5 \text{s} \\ 2.3 \text{s} \\ 4.5 \text{s} \\ 2.3 \text{s} \\ 4.5 \text{s} \\ 27.2 \text{s} \\ 218.3 \text{s} \\ 592.1 \text{s} \\ 175.1 \text{s} \\ 218.2 \text{s} \\ 250.5 \text{s} \\ \end{array}$	800151 Var 351 318 445 1269 1741 3601 4822 6043 10250 16955 16742 8893 13705 14638	$\begin{array}{c} M_{sim} \\ \hline \\ Cnf \\ 1118 \\ 1177 \\ 1765 \\ 4954 \\ 6562 \\ 12815 \\ 16247 \\ 19679 \\ 31940 \\ 49845 \\ 47540 \\ 25474 \\ 39935 \\ 42791 \end{array}$	$\begin{array}{c} T^{sol} \\ 0.8s \\ 0.4s \\ 0.7s \\ 0.8s \\ 1.5s \\ 1.5s \\ 2.2s \\ 3.7s \\ 18.8s \\ 182.2s \\ 460.1s \\ 166.5s \\ 215.0s \\ 208.2s \\ 208.2s \end{array}$			
$\begin{array}{c} {\rm Total} \\ \\ {\rm Round} \\ \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \\ 9 \\ 10 \\ 11 \\ 12 \\ 13 \\ 14 \\ 15 \end{array}$	$\begin{array}{c} \log_2 Cor_{opt} \\ -1 \\ -2 \\ -3 \\ -5 \\ -7 \\ -10 \\ -13 \\ -16 \\ -20 \\ -25 \\ -29 \\ -31 \\ -34 \\ -37 \\ -40 \\ \end{array}$	9163735 <i>Var</i> 351 382 637 2039 3155 7077 10236 13971 24950 41805 43090 25795 45021 52500 60555	$\begin{array}{c} 20504930\\ \hline {\bf mear Pro}\\ \hline M_{sun}\\ \hline Cnf\\ 1150\\ 1337\\ 2245\\ 6879\\ 10033\\ 21216\\ 29106\\ 38244\\ 65986\\ 106810\\ 107342\\ 63539\\ 110115\\ 127317\\ 145767\\ \end{array}$	$\begin{array}{c} 3160.9 \text{s} \\ \hline T^{sol} \\ 1.1 \text{s} \\ 0.3 \text{s} \\ 0.4 \text{s} \\ 0.8 \text{s} \\ 1.5 \text{s} \\ 2.3 \text{s} \\ 2.3 \text{s} \\ 2.3 \text{s} \\ 4.5 \text{s} \\ 27.2 \text{s} \\ 218.3 \text{s} \\ 592.1 \text{s} \\ 175.1 \text{s} \\ 218.2 \text{s} \\ 218.2 \text{s} \\ 500.8 \text{s} \\ 500.8 \text{s} \end{array}$	800151 Var 351 318 445 1269 1741 3601 4822 6043 10250 16955 16742 8893 13705 14638 15571	$\begin{array}{c} M_{sim} \\ Cnf \\ 1118 \\ 1177 \\ 1765 \\ 4954 \\ 6562 \\ 12815 \\ 16247 \\ 19679 \\ 31940 \\ 49845 \\ 47540 \\ 25474 \\ 39935 \\ 42791 \\ 45647 \end{array}$	$\begin{array}{c} 1416.4 \\ \hline T^{sol} \\ 0.8 \\ 0.4 \\ 0.7 \\ 0.8 \\ 0.4 \\ 0.7 \\ 0.8 \\ 0.4 \\ 0.7 \\ 0.8 \\ 0.8 \\ 1.5 \\ 0.8 \\ 1.5 \\ 0.8 \\ 1.5 \\ 0.8 \\ 1.5 \\ 0.8 \\ 2.2 \\ 1.5 \\ 0.8 \\ 2.2 \\ 1.5 \\ 0.8 \\ 2.2 \\ 3.7 \\ 1.5 \\ 1.$			
Total Round 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16	$\begin{array}{c} \log_2 Cor_{opt} \\ -1 \\ -2 \\ -3 \\ -5 \\ -7 \\ -10 \\ -13 \\ -16 \\ -20 \\ -25 \\ -29 \\ -31 \\ -34 \\ -37 \\ -40 \\ -43 \end{array}$	9163735 <i>Var</i> 351 382 637 2039 3155 7077 10236 13971 24950 41805 43090 25795 448021 52500 60555 69186	$\begin{array}{c} 20504930\\ \hline \\ \textbf{mear Pro}\\ \hline \\ M_{sun}\\ \hline \\ Cnf\\ 1150\\ 1337\\ 2245\\ 6879\\ 10033\\ 21216\\ 29106\\ 38244\\ 65986\\ 106810\\ 107342\\ 63539\\ 110115\\ 127317\\ 145767\\ 165465\\ \end{array}$	$\begin{array}{c} 3160.9 \text{s} \\ \hline T^{sol} \\ 1.1 \text{s} \\ 0.3 \text{s} \\ 0.4 \text{s} \\ 0.8 \text{s} \\ 1.5 \text{s} \\ 2.3 \text{s} \\ 4.5 \text{s} \\ 27.2 \text{s} \\ 27.2 \text{s} \\ 218.3 \text{s} \\ 592.1 \text{s} \\ 175.1 \text{s} \\ 218.2 \text{s} \\ 250.5 \text{s} \\ 500.8 \text{s} \\ 462.0 \text{s} \end{array}$	$\begin{array}{c} 800151\\ \hline \\ Var\\ 351\\ 318\\ 445\\ 1269\\ 1741\\ 3601\\ 4822\\ 6043\\ 10250\\ 16955\\ 16742\\ 8893\\ 13705\\ 14638\\ 15571\\ 16504 \end{array}$	$\begin{array}{c} Simplemetric{2}{2} \\ Simplemetric{M}{2} \\ Si$	$\begin{array}{c} T^{sol} \\ \hline 0.88 \\ 0.48 \\ 0.48 \\ 0.78 \\ 0.88 \\ 1.58 \\ 2.28 \\ 3.78 \\ 18.88 \\ 182.28 \\ 460.18 \\ 186.58 \\ 215.08 \\ 208.28 \\ 345.18 \\ 344.28 \end{array}$			
$\begin{array}{c} {\rm Total} \\ \\ {\rm Round} \\ \\ \hline 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \\ 9 \\ 9 \\ 10 \\ 11 \\ 12 \\ 13 \\ 14 \\ 15 \\ 16 \\ 17 \\ \end{array}$	$\begin{array}{c} \log_2 Cor_{opt} \\ -1 \\ -2 \\ -3 \\ -5 \\ -7 \\ -10 \\ -13 \\ -16 \\ -20 \\ -25 \\ -29 \\ -31 \\ -34 \\ -37 \\ -40 \\ -43 \\ -46 \\ \end{array}$	9163735 <i>Var</i> 351 382 637 2039 3155 7077 10236 13971 24950 41805 43090 25795 45021 52500 60555 60186 78393	$\begin{array}{c} 20504930\\ \hline \\ \textbf{mear Pro}\\ \hline \\ \hline$	$\begin{array}{c} 3160.9 \text{s} \\ \hline 3160.9 \text{s} \\ \hline T^{sol} \\ 1.1 \text{s} \\ 0.3 \text{s} \\ 0.4 \text{s} \\ 0.8 \text{s} \\ 0.8 \text{s} \\ 0.8 \text{s} \\ 2.3 \text{s} \\ 4.5 \text{s} \\ 2.3 \text{s} \\ 4.5 \text{s} \\ 218.3 \text{s} \\ 218.3 \text{s} \\ 218.2 \text{s} \\ 218.2 \text{s} \\ 250.5 \text{s} \\ 500.8 \text{s} \\ 500.8 \text{s} \\ 351.7 \text{s} \end{array}$	$\frac{Var}{351}\\\frac{Var}{3601}\\\frac{445}{1269}\\\frac{1741}{3601}\\\frac{4822}{6043}\\\frac{6043}{10250}\\\frac{16955}{16742}\\\frac{8893}{13705}\\\frac{16742}{13705}\\\frac{16504}{17437}$	$\begin{array}{c} Simplemetric{2}{2}\\ Simplemetric{M}{2}\\ Simplemetric{M}{2}\\$	$\begin{array}{c} T^{sol} \\ \hline 0.88 \\ 0.48 \\ 0.48 \\ 0.78 \\ 0.88 \\ 1.58 \\ 2.28 \\ 3.78 \\ 182.28 \\ 460.18 \\ 182.28 \\ 460.18 \\ 182.28 \\ 460.18 \\ 182.28 \\ 315.08 \\ 208.28 \\ 345.18 \\ 344.28 \\ 357.08 \end{array}$			
Total Round 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16	$\begin{array}{c} \log_2 Cor_{opt} \\ -1 \\ -2 \\ -3 \\ -5 \\ -7 \\ -10 \\ -13 \\ -16 \\ -20 \\ -25 \\ -29 \\ -31 \\ -34 \\ -37 \\ -40 \\ -43 \\ -46 \\ -49 \\ \end{array}$	9163735 <i>Var</i> 351 382 637 2039 3155 7077 10236 13971 24950 41805 43090 25795 45021 52500 60555 69186 69186 78393 88176	$\begin{array}{c} 20504930\\ \hline \textbf{mear Pro}\\ \hline M_{sun} \\ \hline Cnf\\ 1150\\ 1337\\ 2245\\ 6879\\ 10033\\ 21216\\ 29106\\ 38244\\ 65986\\ 106810\\ 107342\\ 63539\\ 110115\\ 127317\\ 145767\\ 165465\\ 186411\\ 208605\\ \end{array}$	$\begin{array}{c} 3160.9 \text{s} \\ \hline 3160.9 \text{s} \\ \hline 7100 \text{s}^{sol} \\ \hline 1.1 \text{s} \\ 0.3 \text{s} \\ 0.4 \text{s} \\ 0.8 \text{s} \\ 0.8 \text{s} \\ 1.5 \text{s} \\ 2.3 \text{s} \\ 4.5 \text{s} \\ 2.3 \text{s} \\ 4.5 \text{s} \\ 27.2 \text{s} \\ 218.3 \text{s} \\ 592.1 \text{s} \\ 218.2 \text{s} \\ 250.5 \text{s} \\ 500.8 \text{s} \\ 462.0 \text{s} \\ 351.7 \text{s} \\ 256.1 \text{s} \end{array}$	800151 Var 351 318 445 1269 1741 3601 4822 6043 10250 16955 16742 8893 13705 14638 15571 16504 17437 18370	$\begin{array}{c} Simplemetric{2}{2}\\ Simplemetric{2}{3}\\ Simplemetric{2}{3}\\$	$\begin{array}{c} T^{sol} \\ \hline 0.88 \\ 0.48 \\ 0.78 \\ 0.88 \\ 0.78 \\ 0.78 \\ 0.88 \\ 1.58 \\ 2.28 \\ 3.78 \\ 18.28 \\ 182.28 \\ 460.18 \\ 166.58 \\ 215.08 \\ 208.28 \\ 346.28 \\ 345.18 \\ 344.28 \\ 3457.08 \\ 221.08 \end{array}$			
Total Round 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19	$\begin{array}{c} \log_2 Cor_{opt} \\ -1 \\ -2 \\ -3 \\ -5 \\ -7 \\ -10 \\ -13 \\ -16 \\ -20 \\ -25 \\ -29 \\ -31 \\ -34 \\ -37 \\ -40 \\ -43 \\ -46 \\ -49 \\ -52 \\ \end{array}$	9163735 <i>Var</i> 351 382 637 2039 3155 7077 10236 13971 24950 41805 43090 25795 45021 52500 60555 69186 78393 88176 98535	$\begin{array}{c} 20504930\\ \hline \\ \textbf{mear Pro}\\ \hline \\ \hline$	$\begin{array}{c} 3160.9 \text{s} \\ \hline 3160.9 \text{s} \\ \hline 9 \text{perty} \\ \hline \\ \hline \\ \hline \\ 1.1 \text{s} \\ 0.3 \text{s} \\ 0.4 \text{s} \\ 0.8 \text{s} \\ 0.8 \text{s} \\ 1.5 \text{s} \\ 2.3 \text{s} \\ 4.5 \text{s} \\ 2.3 \text{s} \\ 4.5 \text{s} \\ 27.2 \text{s} \\ 218.3 \text{s} \\ 592.1 \text{s} \\ 175.1 \text{s} \\ 218.2 \text{s} \\ 550.5 \text{s} \\ 500.8 \text{s} \\ 462.0 \text{s} \\ 351.7 \text{s} \\ 256.1 \text{s} \\ 241.0 \text{s} \end{array}$	800151 Var 351 318 445 1269 1741 3601 4822 6043 10250 16955 16742 8893 13705 14638 15571 16504 17437 18370 19303	$\begin{array}{c} M_{sim} \\ Cnf \\ 1118 \\ 1177 \\ 1765 \\ 4954 \\ 6562 \\ 12815 \\ 16247 \\ 19679 \\ 31940 \\ 49845 \\ 47540 \\ 25474 \\ 39935 \\ 42791 \\ 45647 \\ 48503 \\ 51359 \\ 51359 \\ 51215 \\ 57071 \end{array}$	$\begin{array}{c} T^{sol} \\ 0.8s \\ 0.4s \\ 0.7s \\ 0.8s \\ 1.5s \\ 2.2s \\ 3.7s \\ 18.8s \\ 182.2s \\ 460.1s \\ 166.5s \\ 215.0s \\ 208.2s \\ 345.1s \\ 344.2s \\ 345.1s \\ 345.1s \\ 345.3s \\ 221.0s \\ 327.0s \\ 321.0s \\ 330.8s \\ \end{array}$			
$\begin{array}{c} {\rm Total} \\ \\ {\rm Round} \\ \\ \hline 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 7 \\ 8 \\ 9 \\ 10 \\ 11 \\ 12 \\ 13 \\ 14 \\ 15 \\ 16 \\ 17 \\ 18 \\ 19 \\ 20 \\ \end{array}$	$\begin{array}{c} \log_2 Cor_{opt} \\ -1 \\ -2 \\ -3 \\ -5 \\ -7 \\ -10 \\ -13 \\ -16 \\ -20 \\ -25 \\ -29 \\ -31 \\ -34 \\ -37 \\ -40 \\ -43 \\ -43 \\ -46 \\ -49 \\ -52 \\ -55 \\ -55 \end{array}$	9163735 <i>Var</i> 351 382 637 2039 3155 7077 10236 13971 24950 41805 43090 25795 45021 52500 60555 69186 78393 88176 98535 109470	$\begin{array}{c} 20504930\\ \hline mear \ Pro\\ \hline M_{sun} \\ \hline Cnf\\ 1150\\ 1337\\ 2245\\ 6879\\ 10033\\ 21216\\ 29106\\ 38244\\ 65986\\ 106810\\ 107342\\ 65386\\ 106810\\ 107342\\ 105339\\ 110115\\ 127317\\ 145767\\ 165465\\ 186411\\ 208605\\ 232047\\ 256737\\ \end{array}$	$\begin{array}{c} 3160.9 \text{s} \\ \hline 3160.9 \text{s} \\ \hline T^{sol} \\ 1.1 \text{s} \\ 0.3 \text{s} \\ 0.4 \text{s} \\ 0.8 \text{s} \\ 1.5 \text{s} \\ 2.3 \text{s} \\ 2.3 \text{s} \\ 2.3 \text{s} \\ 4.5 \text{s} \\ 27.2 \text{s} \\ 218.3 \text{s} \\ 592.1 \text{s} \\ 175.1 \text{s} \\ 218.2 \text{s} \\ 250.5 \text{s} \\ 500.8 \text{s} \\ 462.0 \text{s} \\ 351.7 \text{s} \\ 256.1 \text{s} \\ 241.0 \text{s} \\ 241.0 \text{s} \\ 2427.0 \text{s} \\ \end{array}$	800151 Var 351 318 445 1269 1741 3601 4822 6043 10250 16955 16742 8893 13705 14638 15571 16504 17437 18370 19303 20236	$\begin{array}{c} M_{sim} \\ \hline Cnf \\ 1118 \\ 1177 \\ 1765 \\ 4954 \\ 6562 \\ 12815 \\ 16247 \\ 19679 \\ 31940 \\ 49845 \\ 47540 \\ 25474 \\ 49845 \\ 47540 \\ 25474 \\ 43935 \\ 42791 \\ 45647 \\ 48503 \\ 51359 \\ 54215 \\ 57071 \\ 59927 \end{array}$	$\begin{array}{c} T^{sol} \\ 0.8s \\ 0.4s \\ 0.7s \\ 0.8s \\ 1.5s \\ 2.2s \\ 3.7s \\ 18.8s \\ 182.2s \\ 460.1s \\ 166.5s \\ 215.0s \\ 208.2s \\ 345.1s \\ 344.2s \\ 357.0s \\ 3210.0s \\ 330.8s \\ 221.9s \\ 330.8s \\ 214.9s \end{array}$			
Total Round 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21	$\begin{array}{c} \log_2 Cor_{opt} \\ -1 \\ -2 \\ -3 \\ -5 \\ -7 \\ -10 \\ -13 \\ -16 \\ -20 \\ -25 \\ -29 \\ -31 \\ -34 \\ -37 \\ -40 \\ -43 \\ -46 \\ -49 \\ -52 \\ -55 \\ -58 \\ -58 \end{array}$	9163735 <i>Var</i> 351 382 637 2039 3155 7077 10236 13971 24950 43090 25795 43090 25795 43090 25795 69186 78393 88176 98535 109470 10941	$\begin{array}{c} 20504930\\ \hline \\ \textbf{mear Pro}\\ \hline \\ M_{sun} \\ \hline \\ Cnf\\ 1150\\ 1337\\ 2245\\ 6879\\ 10033\\ 21216\\ 29106\\ 38244\\ 65986\\ 106810\\ 107342\\ 63539\\ 110115\\ 127317\\ 145767\\ 165465\\ 186411\\ 208605\\ 232047\\ 256737\\ 282675\\ \end{array}$	$\begin{array}{c} 3160.9 \text{s} \\ \hline 3160.9 \text{s} \\ \hline T^{sol} \\ \hline 1.1 \text{s} \\ 0.3 \text{s} \\ 0.4 \text{s} \\ 0.8 \text{s} \\ 1.5 \text{s} \\ 2.3 \text{s} \\ 4.5 \text{s} \\ 2.3 \text{s} \\ 4.5 \text{s} \\ 27.2 \text{s} \\ 218.3 \text{s} \\ 592.1 \text{s} \\ 175.1 \text{s} \\ 218.2 \text{s} \\ 250.5 \text{s} \\ 500.8 \text{s} \\ 462.0 \text{s} \\ 351.7 \text{s} \\ 227.0 \text{s} \\ 227.0 \text{s} \\ 227.0 \text{s} \\ 2266.9 \text{s} \end{array}$	$\begin{array}{c} 800151\\ \hline \\ Var\\ 351\\ 318\\ 445\\ 1269\\ 1741\\ 3601\\ 4822\\ 6043\\ 10250\\ 16955\\ 16742\\ 8893\\ 13705\\ 14638\\ 15571\\ 16504\\ 17437\\ 18370\\ 19303\\ 20236\\ 21169\\ \end{array}$	$\begin{array}{c} Simplemetric{2}{2} \\ Simplemetric{2}{3} \\ Si$	$\begin{array}{c} T^{sol} \\ \hline 0.88 \\ 0.48 \\ 0.78 \\ 0.88 \\ 1.58 \\ 2.28 \\ 3.78 \\ 18.88 \\ 182.28 \\ 460.18 \\ 186.58 \\ 215.08 \\ 208.28 \\ 345.18 \\ 344.28 \\ 357.08 \\ 221.08 \\ 330.88 \\ 214.98 \\ 338.58 \\ 338.58 \end{array}$			
$\begin{array}{c} {\rm Total} \\ \\ {\rm Round} \\ \\ \hline 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \\ 9 \\ 10 \\ 11 \\ 12 \\ 13 \\ 14 \\ 15 \\ 16 \\ 17 \\ 18 \\ 19 \\ 20 \\ 21 \\ 22 \\ \end{array}$	$\begin{array}{c} \log_2 Cor_{opt} \\ -1 \\ -2 \\ -3 \\ -5 \\ -7 \\ -10 \\ -13 \\ -16 \\ -20 \\ -25 \\ -29 \\ -31 \\ -34 \\ -37 \\ -40 \\ -43 \\ -46 \\ -49 \\ -52 \\ -55 \\ -58 \\ -61 \\ \end{array}$	9163735 <i>Var</i> 351 382 637 2039 3155 7077 10236 13971 24950 41805 43090 25795 45021 52500 60555 45021 52500 60586 78393 88176 98535 109470 120981 133068	$\begin{array}{c} 20504930\\ \hline \\ \textbf{mear Pro}\\ \hline \\ \hline$	$\begin{array}{c} 3160.9 \mathrm{s} \\ \hline 3160.9 \mathrm{s} \\ \hline T^{sol} \\ 1.1 \mathrm{s} \\ 0.3 \mathrm{s} \\ 0.4 \mathrm{s} \\ 0.8 \mathrm{s} \\ 0.8 \mathrm{s} \\ 0.8 \mathrm{s} \\ 2.3 \mathrm{s} \\ 4.5 \mathrm{s} \\ 2.3 \mathrm{s} \\ 4.5 \mathrm{s} \\ 218.3 \mathrm{s} \\ 218.3 \mathrm{s} \\ 218.3 \mathrm{s} \\ 218.3 \mathrm{s} \\ 250.5 \mathrm{s} \\ 592.1 \mathrm{s} \\ 175.1 \mathrm{s} \\ 218.2 \mathrm{s} \\ 250.5 \mathrm{s} \\ 500.8 \mathrm{s} \\ 500.8 \mathrm{s} \\ 250.5 \mathrm{s} \\ 500.8 \mathrm{s} \\ 250.6 \mathrm{s} \\ 256.1 \mathrm{s} \\ 241.0 \mathrm{s} \\ 227.0 \mathrm{s} \\ 266.9 \mathrm{s} \\ 253.0 \mathrm{s} \end{array}$	$\frac{Var}{351}\\\frac{Var}{3601}\\\frac{445}{1269}\\1741\\\frac{3601}{4822}\\6043\\10250\\16955\\16742\\\frac{8893}{13705}\\16742\\\frac{8893}{13705}\\16742\\\frac{17437}{18370}\\19303\\20236\\21169\\22102\\$	$\begin{array}{c} Simplemetric{2}{2} \\ Simplemetric{2}{3} \\ Si$	$\begin{array}{c} T^{sol} \\ 0.88 \\ 0.48 \\ 0.48 \\ 0.78 \\ 0.88 \\ 1.58 \\ 2.28 \\ 3.78 \\ 182.28 \\ 460.18 \\ 182.28 \\ 460.18 \\ 182.28 \\ 460.18 \\ 182.28 \\ 3182.28 \\ 460.18 \\ 132.08 \\ 215.08 \\ 208.28 \\ 345.18 \\ 3$			
Total Round 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21	$\begin{array}{c} \log_2 Cor_{opt} \\ -1 \\ -2 \\ -3 \\ -5 \\ -7 \\ -10 \\ -13 \\ -16 \\ -20 \\ -25 \\ -29 \\ -31 \\ -34 \\ -37 \\ -40 \\ -43 \\ -46 \\ -49 \\ -52 \\ -55 \\ -58 \\ -58 \end{array}$	9163735 <i>Var</i> 351 382 637 2039 3155 7077 10236 13971 24950 41805 43090 25795 45021 52500 60555 69186 69186 78393 88176 98535 109470 120981 133068 145731	$\begin{array}{c} 20504930\\ \hline \\ \textbf{mear Pro}\\ \hline \\ \hline$	$\begin{array}{c} 3160.9 \mathrm{s} \\ \hline 3160.9 \mathrm{s} \\ \hline 75 \mathrm{s}^{sol} \\ \hline 1.1 \mathrm{s} \\ 0.3 \mathrm{s} \\ 0.4 \mathrm{s} \\ 0.8 \mathrm{s} \\ 0.8 \mathrm{s} \\ 1.5 \mathrm{s} \\ 2.3 \mathrm{s} \\ 4.5 \mathrm{s} \\ 2.3 \mathrm{s} \\ 4.5 \mathrm{s} \\ 218.3 \mathrm{s} \\ 592.1 \mathrm{s} \\ 218.3 \mathrm{s} \\ 592.1 \mathrm{s} \\ 218.2 \mathrm{s} \\ 250.5 \mathrm{s} \\ 500.8 \mathrm{s} \\ 462.0 \mathrm{s} \\ 351.7 \mathrm{s} \\ 2250.8 \mathrm{s} \\ 241.0 \mathrm{s} \\ 227.0 \mathrm{s} \\ 266.1 \mathrm{s} \\ 227.0 \mathrm{s} \\ 263.0 \mathrm{s} \\ 253.0 \mathrm{s} \\ 309.1 \mathrm{s} \end{array}$	800151 Var 351 318 445 1269 1741 3601 4822 6043 10250 16955 16742 8893 13705 14638 15571 16504 17437 18370 19303 20236 21169 22102 23035	$\begin{array}{c} Simplemetric{2}{2} \\ Simplemetric{2}{3} \\ Si$	$\begin{array}{c} T^{sol} \\ \hline 0.88 \\ 0.48 \\ 0.78 \\ 0.88 \\ 0.78 \\ 0.78 \\ 0.88 \\ 1.58 \\ 2.28 \\ 3.78 \\ 18.28 \\ 182.28 \\ 460.18 \\ 166.58 \\ 215.08 \\ 208.28 \\ 346.28 \\ 208.28 \\ 345.18 \\ 3357.08 \\ 221.08 \\ 330.88 \\ 221.08 \\ 330.88 \\ 214.98 \\ 338.58 \\ 338.58 \\ 307.08 \\ 310.48 \\ \end{array}$			
$\begin{array}{c} {\rm Total} \\ \\ {\rm Round} \\ \\ \hline 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \\ 9 \\ 10 \\ 11 \\ 12 \\ 13 \\ 14 \\ 15 \\ 16 \\ 17 \\ 18 \\ 19 \\ 20 \\ 21 \\ 22 \\ \end{array}$	$\begin{array}{c} \log_2 Cor_{opt} \\ -1 \\ -2 \\ -3 \\ -5 \\ -7 \\ -10 \\ -13 \\ -16 \\ -20 \\ -25 \\ -29 \\ -31 \\ -34 \\ -37 \\ -40 \\ -43 \\ -46 \\ -49 \\ -52 \\ -55 \\ -58 \\ -61 \\ \end{array}$	9163735 <i>Var</i> 351 382 637 2039 3155 7077 10236 13971 24950 41805 43090 25795 45021 52500 60555 45021 52500 60586 78393 88176 98535 109470 120981 133068	$\begin{array}{c} 20504930\\ \hline \\ \textbf{mear Pro}\\ \hline \\ \hline$	$\begin{array}{c} 3160.9 \mathrm{s} \\ \hline 3160.9 \mathrm{s} \\ \hline 7100 \mathrm{s}^{sol} \\ \hline 1.1 \mathrm{s} \\ 0.3 \mathrm{s} \\ 0.4 \mathrm{s} \\ 0.8 \mathrm{s} \\ 0.8 \mathrm{s} \\ 0.8 \mathrm{s} \\ 1.5 \mathrm{s} \\ 2.3 \mathrm{s} \\ 4.5 \mathrm{s} \\ 27.2 \mathrm{s} \\ 218.3 \mathrm{s} \\ 592.1 \mathrm{s} \\ 218.3 \mathrm{s} \\ 250.5 \mathrm{s} \\ 500.8 \mathrm{s} \\ 462.0 \mathrm{s} \\ 351.7 \mathrm{s} \\ 256.1 \mathrm{s} \\ 241.0 \mathrm{s} \\ 227.0 \mathrm{s} \\ 266.9 \mathrm{s} \\ 253.0 \mathrm{s} \\ 309.1 \mathrm{s} \\ 271.8 \mathrm{s} \end{array}$	$\frac{Var}{351}\\\frac{Var}{3601}\\\frac{445}{1269}\\1741\\\frac{3601}{4822}\\6043\\10250\\16955\\16742\\\frac{8893}{13705}\\16742\\\frac{8893}{13705}\\16742\\\frac{17437}{18370}\\19303\\20236\\21169\\22102\\$	$\begin{array}{c} Simplemetric{2}{2} \\ Simplemetric{2}{3} \\ Si$	$\begin{array}{c} T^{sol} \\ 0.8s \\ 0.4s \\ 0.7s \\ 0.8s \\ 0.7s \\ 0.8s \\ 1.5s \\ 2.2s \\ 3.7s \\ 18.2s \\ 182.2s \\ 460.1s \\ 166.5s \\ 215.0s \\ 208.2s \\ 345.1s \\ 344.2s \\ 357.0s \\ 221.0s \\ 330.8s \\ 214.9s \\ 338.5s \\ 338.5s \\ 337.0s \\ 310.4s \\ 310.4s \end{array}$			
Total Round 1 2 3 4 5 6 7 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23	$\begin{array}{c} \log_2 Cor_{opt} \\ -1 \\ -2 \\ -3 \\ -5 \\ -7 \\ -10 \\ -13 \\ -16 \\ -20 \\ -25 \\ -29 \\ -31 \\ -34 \\ -37 \\ -40 \\ -43 \\ -46 \\ -49 \\ -52 \\ -55 \\ -58 \\ -61 \\ -64 \\ \end{array}$	9163735 <i>Var</i> 351 382 637 2039 3155 7077 10236 13971 24950 41805 43090 25795 45021 52500 60555 69186 69186 78393 88176 98535 109470 120981 133068 145731	$\begin{array}{c} 20504930\\ \hline \\ \textbf{mear Pro}\\ \hline \\ \hline$	$\begin{array}{c} 3160.9 \mathrm{s} \\ \hline 3160.9 \mathrm{s} \\ \hline 9 \mathrm{perty} \\ \hline 1.1 \mathrm{s} \\ 0.3 \mathrm{s} \\ 0.4 \mathrm{s} \\ 0.8 \mathrm{s} \\ 0.8 \mathrm{s} \\ 1.5 \mathrm{s} \\ 2.3 \mathrm{s} \\ 4.5 \mathrm{s} \\ 27.2 \mathrm{s} \\ 218.3 \mathrm{s} \\ 592.1 \mathrm{s} \\ 175.1 \mathrm{s} \\ 218.2 \mathrm{s} \\ 550.8 \mathrm{s} \\ 462.0 \mathrm{s} \\ 351.7 \mathrm{s} \\ 256.1 \mathrm{s} \\ 241.0 \mathrm{s} \\ 227.0 \mathrm{s} \\ 266.9 \mathrm{s} \\ 256.3 \mathrm{o} \\ 309.1 \mathrm{s} \\ 230.9 \mathrm{s} \\ 230.9 \mathrm{s} \\ 230.9 \mathrm{s} \\ 271.8 \mathrm{s} \\ 264.5 \mathrm{s} \\ 264.5 \mathrm{s} \end{array}$	800151 Var 351 318 445 1269 1741 3601 4822 6043 10250 16955 16742 8893 13705 14638 15571 16504 17437 18370 19303 20236 21169 22102 23035 23968 24901	$\begin{array}{c} M_{sim} \\ Cnf \\ Cnf \\ 1118 \\ 1177 \\ 1765 \\ 4954 \\ 6562 \\ 12815 \\ 16247 \\ 19679 \\ 31940 \\ 49845 \\ 47540 \\ 25474 \\ 47540 \\ 25474 \\ 43935 \\ 42791 \\ 45647 \\ 48503 \\ 51359 \\ 54215 \\ 57071 \\ 59927 \\ 62783 \\ 65639 \\ 68495 \\ 71351 \\ 74207 \end{array}$	$\begin{array}{c} T^{sol} \\ 0.88 \\ 0.48 \\ 0.78 \\ 0.88 \\ 0.78 \\ 0.78 \\ 0.88 \\ 1.58 \\ 2.28 \\ 3.78 \\ 18.28 \\ 460.18 \\ 215.08 \\ 208.28 \\ 344.28 \\ 344.28 \\ 3457.08 \\ 221.08 \\ 330.88 \\ 214.98 \\ 338.58 \\ 3307.08 \\ 310.48 \\ 225.88 \end{array}$			
Total Round 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 21 22 23 24	$\begin{array}{c} \log_2 Cor_{opt} \\ -1 \\ -2 \\ -3 \\ -5 \\ -7 \\ -10 \\ -13 \\ -16 \\ -20 \\ -25 \\ -29 \\ -31 \\ -34 \\ -34 \\ -34 \\ -34 \\ -37 \\ -40 \\ -43 \\ -46 \\ -49 \\ -55 \\ -58 \\ -61 \\ -64 \\ -67 \\ -70 \\ -73 \\ \end{array}$	9163735 <i>Var</i> 351 382 637 2039 3155 7077 10236 13971 24950 43090 25795 43090 25795 43090 25795 43090 25795 69186 78393 88176 98535 109470 120981 133068 145731 158970 172785 187176	$\begin{array}{c} 20504930\\ \hline \\ \textbf{mear Pro}\\ \hline \\ M_{sun} \\ \hline \\ Cnf\\ 1150\\ 1337\\ 2245\\ 6879\\ 10033\\ 21216\\ 29106\\ 38244\\ 65986\\ 106810\\ 107342\\ 63539\\ 110115\\ 127317\\ 145767\\ 165465\\ 186411\\ 208605\\ 232047\\ 256737\\ 282675\\ 309861\\ 338295\\ 367977\\ 398907\\ 431085\\ \end{array}$	$\begin{array}{c} 3160.9 \text{s} \\ \hline 3160.9 \text{s} \\ \hline T^{sol} \\ \hline 1.1 \text{s} \\ 0.3 \text{s} \\ 0.4 \text{s} \\ 0.8 \text{s} \\ 1.5 \text{s} \\ 2.3 \text{s} \\ 4.5 \text{s} \\ 27.8 \text{s} \\ 592.1 \text{s} \\ 175.1 \text{s} \\ 218.2 \text{s} \\ 250.5 \text{s} \\ 500.8 \text{s} \\ 462.0 \text{s} \\ 351.7 \text{s} \\ 226.0 \text{s} \\ 227.0 \text{s} \\ 227.0 \text{s} \\ 2266.9 \text{s} \\ 253.0 \text{s} \\ 309.1 \text{s} \\ 271.8 \text{s} \\ 264.5 \text{s} \\ 283.2 \text{s} \\ \end{array}$	800151           Var           351           318           445           1269           1741           3601           4822           6043           10250           16955           16742           8893           13705           14638           15571           16504           17437           18370           19303           20236           23968           24901           25834	$\begin{array}{c} Simplemetric{2}{2} \\ Simplemetric{2}{3} \\ Si$	$\begin{array}{c} T^{sol} \\ \hline 0.88 \\ 0.48 \\ 0.48 \\ 0.78 \\ 0.88 \\ 1.58 \\ 2.28 \\ 3.78 \\ 182.28 \\ 460.18 \\ 182.28 \\ 460.18 \\ 182.28 \\ 460.18 \\ 182.28 \\ 3182.28 \\ 345.18 \\ 344.28 \\ 357.08 \\ 221.08 \\ 330.88 \\$			
Total Round 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 18 19 20 21 22 22 22 24 25	$\begin{array}{c} \log_2 Cor_{opt} \\ -1 \\ -2 \\ -3 \\ -5 \\ -7 \\ -10 \\ -13 \\ -16 \\ -20 \\ -25 \\ -29 \\ -31 \\ -34 \\ -37 \\ -40 \\ -43 \\ -46 \\ -49 \\ -52 \\ -58 \\ -61 \\ -64 \\ -67 \\ -70 \\ -73 \\ -76 \\ \end{array}$	9163735 Var 351 382 637 2039 3155 7077 10236 13971 24950 41805 43090 25795 45021 52500 60555 69186 78393 88176 98535 109470 120981 133068 145731 158970 172785	$\begin{array}{c} 20504930\\ \hline \textbf{mear Pro}\\ \hline M_{sun} \\ \hline Cnf\\ 1150\\ 1337\\ 2245\\ 6879\\ 10033\\ 21216\\ 29106\\ 38244\\ 65986\\ 106810\\ 107342\\ 63539\\ 110115\\ 127317\\ 145767\\ 165465\\ 186411\\ 208605\\ 232047\\ 256737\\ 282675\\ 309861\\ 338295\\ 367977\\ 398907\\ \end{array}$	$\begin{array}{c} 3160.9 \mathrm{s} \\ \hline 3160.9 \mathrm{s} \\ \hline 9 \mathrm{perty} \\ \hline 1.1 \mathrm{s} \\ 0.3 \mathrm{s} \\ 0.4 \mathrm{s} \\ 0.8 \mathrm{s} \\ 0.8 \mathrm{s} \\ 1.5 \mathrm{s} \\ 2.3 \mathrm{s} \\ 4.5 \mathrm{s} \\ 27.2 \mathrm{s} \\ 218.3 \mathrm{s} \\ 592.1 \mathrm{s} \\ 175.1 \mathrm{s} \\ 218.2 \mathrm{s} \\ 550.8 \mathrm{s} \\ 462.0 \mathrm{s} \\ 351.7 \mathrm{s} \\ 256.1 \mathrm{s} \\ 241.0 \mathrm{s} \\ 227.0 \mathrm{s} \\ 266.9 \mathrm{s} \\ 256.3 \mathrm{o} \\ 309.1 \mathrm{s} \\ 271.8 \mathrm{s} \\ 201.8 \mathrm{s} \\ 211.8 \mathrm{s} \\ 264.5 \mathrm{s} \\ 264.5 \mathrm{s} \\ \end{array}$	800151 Var 351 318 445 1269 1741 3601 4822 6043 10250 16955 16742 8893 13705 14638 15571 16504 17437 18370 19303 20236 21169 22102 23035 23968 24901	$\begin{array}{c} M_{sim} \\ Cnf \\ Cnf \\ 1118 \\ 1177 \\ 1765 \\ 4954 \\ 6562 \\ 12815 \\ 16247 \\ 19679 \\ 31940 \\ 49845 \\ 47540 \\ 25474 \\ 47540 \\ 25474 \\ 43935 \\ 42791 \\ 45647 \\ 48503 \\ 51359 \\ 54215 \\ 57071 \\ 59927 \\ 62783 \\ 65639 \\ 68495 \\ 71351 \\ 74207 \end{array}$	$\begin{array}{c} T^{sol} \\ \hline 0.88 \\ 0.48 \\ 0.78 \\ 0.88 \\ 0.78 \\ 0.78 \\ 0.88 \\ 1.58 \\ 2.28 \\ 3.78 \\ 18.28 \\ 182.28 \\ 460.18 \\ 166.58 \\ 215.08 \\ 208.28 \\ 346.28 \\ 346.28 \\ 345.18 \\ 3357.08 \\ 221.08 \\ 330.88 \\ 214.98 \\ 338.58 \\ 338.58 \\ 307.08 \\ 310.48 \end{array}$			
Total Round 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26	$\begin{array}{c} \log_2 Cor_{opt} \\ -1 \\ -2 \\ -3 \\ -5 \\ -7 \\ -10 \\ -13 \\ -16 \\ -20 \\ -25 \\ -29 \\ -31 \\ -34 \\ -34 \\ -34 \\ -34 \\ -37 \\ -40 \\ -43 \\ -46 \\ -49 \\ -55 \\ -58 \\ -61 \\ -64 \\ -67 \\ -70 \\ -73 \\ \end{array}$	9163735 <i>Var</i> 351 382 637 2039 3155 7077 10236 13971 24950 43090 25795 43090 25795 43090 25795 43090 25795 69186 78393 88176 98535 109470 120981 133068 145731 158970 172785 187176	$\begin{array}{c} 20504930\\ \hline \\ \textbf{mear Pro}\\ \hline \\ M_{sun} \\ \hline \\ Cnf\\ 1150\\ 1337\\ 2245\\ 6879\\ 10033\\ 21216\\ 29106\\ 38244\\ 65986\\ 106810\\ 107342\\ 63539\\ 110115\\ 127317\\ 145767\\ 165465\\ 186411\\ 208605\\ 232047\\ 256737\\ 282675\\ 309861\\ 338295\\ 367977\\ 398907\\ 431085\\ \end{array}$	$\begin{array}{c} 3160.9 \mathrm{s} \\ \hline 3160.9 \mathrm{s} \\ \hline 75 \mathrm{s}^{cl} \\ \hline 1.1 \mathrm{s} \\ 0.3 \mathrm{s} \\ 0.4 \mathrm{s} \\ 0.8 \mathrm{s} \\ 0.8 \mathrm{s} \\ 1.5 \mathrm{s} \\ 2.3 \mathrm{s} \\ 4.5 \mathrm{s} \\ 2.3 \mathrm{s} \\ 4.5 \mathrm{s} \\ 218.3 \mathrm{s} \\ 592.1 \mathrm{s} \\ 175.1 \mathrm{s} \\ 218.2 \mathrm{s} \\ 250.5 \mathrm{s} \\ 500.8 \mathrm{s} \\ 462.0 \mathrm{s} \\ 351.7 \mathrm{s} \\ 226.9 \mathrm{s} \\ 227.0 \mathrm{s} \\ 226.6 \mathrm{s} \\ 253.0 \mathrm{s} \\ 309.1 \mathrm{s} \\ 271.8 \mathrm{s} \\ 285.6 \mathrm{s} \\ 283.2 \mathrm{s} \\ 285.6 \mathrm{s} \\ 311.7 \mathrm{s} \end{array}$	800151 Var 351 318 445 1269 1741 3601 4822 6043 10250 16955 16742 8893 13705 16742 8893 13705 16742 8893 13705 16955 16742 8893 13705 16955 16742 8893 13705 16955 16742 8893 13705 16955 16742 8893 13705 16955 16742 8893 13705 16955 16742 8893 13705 16955 16742 8893 13705 16955 16742 8893 13705 16955 16742 8893 13705 16955 16742 8893 13705 16955 16742 8893 13705 16955 16742 16504 16955 16742 16504 16955 16742 16504 16955 16742 16504 16955 16742 16504 16955 16742 16504 16955 16742 16504 16955 16742 16504 16955 16742 16504 16955 16742 16504 16955 16742 16504 16955 16745 16504 16955 16745 16504	$\begin{array}{c} Simplemetric{2}{2} \\ Simplemetric{2}{3} \\ Si$	$\begin{array}{c} T^{sol} \\ \hline 0.88 \\ 0.48 \\ 0.48 \\ 0.78 \\ 0.88 \\ 1.58 \\ 2.28 \\ 3.78 \\ 182.28 \\ 460.18 \\ 182.28 \\ 460.18 \\ 182.28 \\ 460.18 \\ 182.28 \\ 3182.28 \\ 345.18 \\ 344.28 \\ 357.08 \\ 221.08 \\ 330.88 \\$			

Differential Property										
			M <sub>sun</sub>			$M_{sim}$				
Round	$\log_2 P_{opt}$	Var	Cnf	$T^{sol}$	Var	Cnf	$T^{sol}$			
1	-1.415	1182	5499	0.2s	1182	5403	0.2s			
2	-3.415	3128	13381	0.2s	2548	11931	0.2s			
- 3	-7	11939	42911	0.7s	8057	33693	0.5s			
4	-11.415	23375	73502	1.5s	12713	49269	1.4s			
5	-17	48201	137955	7.9s	22631	80998	6.9s			
6	-22.415	78022	208308	19.7s	32698	108934	17.8s			
7	-28.415	131979	337655	98.1s	49363	158179	83.3s			
8	-39	305162	746449	3832.1s	115588	337447	2553.6s			
9	-45.415	272180	645604	2657.7s	98536	273887	1867.7s			
10	-49.415	239761	562598	542.7s	72419	206125	201.9s			
11	-54.415	345062	802966	726.5s	87710	256334	115.0s			
12	-60.415	483563	1114804	2172.2s	110573	324151	229.8s			
13	-67.83	664028	1515923	7202.8s	145314	418180	1015.5s			
14	-79	1218318	2747022	154725.1s	316984	856761	29013.6s			
15	-85.415	856156	1912402	82353.6s	204874	538803	16675.4s			
16	-90.415	833262	1854320	23703.7s	176946	472134	2261.1s			
17	-96.415	1095855	2430141	28299.3s	209023	564547	6249.6s			
18	-103.415	1416604	3128587	98258.3s	255346	687908	10032.7s			
19	-110.83	1597380	3513947	153129.3s	277578	742308	10032.7s 10794.1s			
20	-121.415	2729099	5973181	2679475.9s	495133	1285212	544635.4s			
20	-126.415	1528822	3334794	128549.4s	272002	699574	29560.2s			
21 22	-132.415	1950067	4246118	87235.3s	314263	818523	19879.2s			
22	-139.415	2444925	5311943	159346.3s	272403	971688	48047.9s			
23	-146.83	2680964	5811667	222371.8s	394602	1026020	95098.1s			
24	-157.415	4447707	9611825	2680211.5s	680957	1731196	1021543.7s			
26	-162.415	2431742	5244388	138927.1s	367058	927014	72698.5s			
20	-168.415	3046199	6562735	284765.3s	419503	1072499	128264.8s			
28	-174.415	3271885	7041002	302579.7s	419187	1072433	143142.4s			
29	-181.83	4018764	8637027	454797.7s	490994	1268484	202086.2s			
Total	-101.05	38175331		7695991.6s	7265067	19127269	2366197.5s			
30	-193	-	-	-	838882	2119484	1548721.8s			
31	-198.415	-	-	-	464358	1158942	137815.9s			
32	-204.415	-	-	-	527361	1331711	191841.5s			
33	-210.415	-	-	-	523013	1331731	200005.4s			
34	-217.415	-	-	_	607170	1550500	242581.9s			
35	-224.83	-	-	-	627866	1601828	211591.8s			
36	234.415	-	-	-	947853	2384355	1191166.5s			
37	240.415	-	-	-	642079	1604643	258131.2s			
38	240.415	-	-	-	633699	1596599	313064.2s			
39	253.415	-	-	-	729939	1845704	115049.5s			
40	260.415	-	-	-	644931	1633919	474680.7s			
40	200.410	_	Linear	Property	011331	1055515	414000.13			
Daum 1	lan Car		M <sub>sun</sub>			M <sub>sim</sub>				
round	$\log_2 Cor_{opt}$	Var	Cnf	$T^{sol}$	Var	Cnf	$T^{sol}$			
1	-1	703	2302	1.0s	703	2238	0.8s			
2	-2	766	2681	0.4s	638	2361	0.5s			
3	-3	1277	4501	0.4s	893	3541	0.4s			
4	-5	4087	13791	0.9s	2549	9946	1.0s			
5	-7	6323	20113	1.0s	3501	13186	1.3s			
6	-10	14181	42528	2.1s	7249	25775	1.9s			
7	-13	20508	58338	4.8s	9718	32711	4.6s			
8	-17	38338	104234	24.0s	17262	54884	25.9s			
9	-22	66780	173900	234.0s	29480	87725	224.1s			

 Table 7. Experimental results of GIFT128

Round	$\log_2 Cor_{opt}$		Wisun			$M_{sim}$	
nound	log <sub>2</sub> Cor <sub>opt</sub>	Var	Cnf	$T^{sol}$	Var	Cnf	$T^{sol}$
1	-1	703	2302	1.0s	703	2238	0.8s
2	-2	766	2681	0.4s	638	2361	0.5s
3	-3	1277	4501	0.4s	893	3541	0.4s
4	-5	4087	13791	0.9s	2549	9946	1.0s
5	-7	6323	20113	1.0s	3501	13186	1.3s
6	-10	14181	42528	2.1s	7249	25775	1.9s
7	-13	20508	58338	4.8s	9718	32711	4.6s
8	-17	38338	104234	24.0s	17262	54884	25.9s
9	-22	66780	173900	234.0s	29480	87725	224.1s
10	-26	70814	178870	640.3s	29642	84948	721.0s
11	-31	113135	279355	4804.3s	44955	125305	5587.3s
12	-36	142550	345035	28270.0s	54430	147565	25064.7s
13	-38	67573	161991	5045.4s	23083	62978	1329.7s
14	-41	115848	276465	10202.9s	24510	96239	7672.0s
15	-45	178898	423742	15362.0s	49422	137796	15227.4s
16	-48	153843	342028	10751.9s	39427	110063	3818.8s
17	-51	173226	405870	4591.6s	40360	113927	4207.0s
18	-56	328690	765185	19648.9s	74550	207765	20826.5s
19	-59	222738	515616	9483.1s	48706	134603	13455.1s
20	-64	416330	958975	80615.3	88460	242225	63578.4s
21	-68	373878	856594	148642.6s	78746	212388	86316.8s
22	-74	629715	1434747	1931535.4s	134681	355678	1278924.8s
23	-79	589055	1334575	1208961.7s	129035	333305	691225.2s
24	-82	387213	874722	206139.3s	80821	208775	89751.8s
25	-86	560174	1262890	584729.2s	109634	284772	305487.9s
Total		4676643	10859048	4272597.4s	1132455	3090699	2613454.2s
26	-91	-	-	-	147345	379885	3580030.2s
27	-94	-	-	-	91807	236723	2274569.6s

Table	8.	Experimental	results	of	LBlock
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		Dille	rential F	roper	ιy		
Round	$\log_2 P_{opt}$		M <sub>sun</sub>	$T^{sol}$	¥ 7	Msim	$T^{sol}$
	-	Var	Cnf	-	Var	Cnf	-
1	0	184	546	0.1s	184	522	0.1s
2	-2	1053	3524	0.2s	1051	3401	0.2s
3	-4	1911	6169	0.2s	1615	5360	0.2s
4	-6	3057	9511	0.2s	2179	7319	0.2s
5	-8	4491	13501	0.3s	2743	9278	0.2s
6	-12	11070	31656	0.5s	6210	20115	0.5s
7	-16	16210	44036	0.7s	8410	25880	0.5s
8	-22	32571	84505	1.8s	16149	46879	1.2s
9	-28	45633	113891	2.8s	21609	59682	1.8s
10	-36	80208	193906	5.0s	36876	97323	3.4s
11	-44	107136	252370	8.5s	47748	121452	5.8s
12	-48	73530	170916	4.0s	29770	75305	2.3s
13	-56	160164	368326	13.3s	60420	151638	9.2s
14	-62	150563	342553	14.1s	53837	133497	10.0s
15	-66	124200	281046	9.2s	40110	100020	6.2s
16	-72	198877	447903	13.4s	58849	147315	11.4s
17	-76	161110	361336	11.7s	43690	109890	7.7s
18	-82	253911	567365	19.0s	63861	161133	12.8s
19	-82	202820	451706	20.8s	47270	119760	12.6s
20	-92	315665	700939	20.8s 20.7s	68873	174951	13.0s 14.7s
21	-96	249330	552156	11.7s	50850	129630	6.5s
22	-102	384139	848625	18.2s	73885	188769	11.6s
23	-106	300640	662686	20.5s	54430	139500	9.7s
24	-112	459333	1010423	21.8s	78897	202587	9.7s
25	-115	284202	624243	10.4s	45218	117120	5.7s
26	-121	536886	1177618	22.3s	79926	208453	12.1s
27	-126	499251	1092904	36.3s	72563	188404	16.5s
28	-131	537885	1175710	26.5s	74789	194482	10.8s
29	-135	479895	1047811	17.3s	62455	163690	8.4s
30	-141	720202	1570430	34.3s	90300	236789	9.6s
31	-146	662427	1442272	54.5s	81743	213268	18.5s
	-140						
32							
T. 4 . 1	-101	706821	1537174	39.2s	83969	219346	
Total	-101	7765375	1537174 7187757 near Pro	456.3s	83969 1460479	219346 3772758	
		7765375 Lir	7187757 near Pro $M_{sun}$	456.3s	1460479	3772758 M <sub>sim</sub>	237.3
Round	$\log_2 Cor_{opt}$	7765375 Lir Var	$\begin{array}{c} 7187757\\ \textbf{near Pro}\\ \hline M_{sun}\\ \hline Cnf \end{array}$	456.3s <b>perty</b> T <sup>sol</sup>	1460479 Var	$\frac{M_{sim}}{Cnf}$	237.3
Round	$\log_2 Cor_{opt}$	7765375 Lir Var 176	$7187757$ near Pro $M_{sun}$ $Cnf$ $481$	456.3s <b>perty</b> T <sup>sol</sup> 0.1s	1460479 Var 176	$\begin{array}{c} 3772758\\ \hline M_{sim}\\ \hline Cnf\\ 465 \end{array}$	$\frac{237.3}{T^{sol}}$
Round 1 2	$\log_2 Cor_{opt}$ 0 -1	7765375 Lir Var 176 623	$\begin{array}{c} 7187757 \\ \textbf{near Pro} \\ \hline M_{sun} \\ \hline Cnf \\ 481 \\ 1981 \\ \end{array}$	456.3s perty T <sup>sol</sup> 0.1s 0.1s	1460479 Var 176 607	3772758 $M_{sim}$ Cnf 465 1918	237.3 $T^{sol}$ 0.1 0.1s
Round	$\frac{\log_2 Cor_{opt}}{0}$	7765375 Lir Var 176	$7187757$ near Pro $M_{sun}$ $Cnf$ $481$	456.3s <b>perty</b> T <sup>sol</sup> 0.1s	1460479 Var 176 607 877	$\begin{array}{c} 3772758\\ \hline M_{sim}\\ \hline Cnf\\ 465 \end{array}$	$\frac{237.3}{T^{sol}}$
Round 1 2	$\log_2 Cor_{opt}$ 0 -1	7765375 Lir Var 176 623	$\begin{array}{c} 7187757 \\ \textbf{near Pro} \\ \hline M_{sun} \\ \hline Cnf \\ 481 \\ 1981 \\ \end{array}$	456.3s perty T <sup>sol</sup> 0.1s 0.1s	1460479 Var 176 607	3772758 $M_{sim}$ Cnf 465 1918	237.3 $T^{sol}$ 0.1s 0.1s
$\frac{1}{2}$	$\frac{\log_2 Cor_{opt}}{0}$	7765375 Lir Var 176 623 1013	$7187757$ <b>near Pro</b> $M_{sun}$ $Cnf$ $481$ $1981$ $3156$	456.3s <b>perty</b> $T^{sol}$ 0.1s 0.1s 0.1s	1460479 Var 176 607 877	$\frac{M_{sim}}{Cnf} \\ \frac{465}{1918} \\ 2934$	237.3 $T^{sol}$ 0.1s 0.1s 0.1s
Round 1 2 3 4	$log_2 Cor_{opt}$ 0 -1 -2 -3	7765375 Lin Var 176 623 1013 1499	$\begin{array}{c} 7187757 \\ \hline \mathbf{near Pro} \\ \hline M_{sun} \\ \hline Cnf \\ 481 \\ 1981 \\ 3156 \\ 4524 \end{array}$	$\begin{array}{c} 456.3 \text{s} \\ \textbf{perty} \\ \hline \\ T^{sol} \\ 0.1 \text{s} \end{array}$	1460479 Var 176 607 877 1147	$\frac{M_{sim}}{Cnf} \\ \frac{465}{1918} \\ 2934 \\ 3950 \\ \end{array}$	$\begin{array}{c} 237.3 \\ \hline T^{sol} \\ 0.1s \\ 0.1s \\ 0.1s \\ 0.1s \\ 0.1s \\ 0.1s \end{array}$
Round 1 2 3 4 5	$log_2 Cor_{opt}$ 0 -1 -2 -3 -4	7765375 Lir Var 176 623 1013 1499 2081 4353	$\begin{array}{c} 7187757 \\ \textbf{near Pro} \\ \hline M_{sun} \\ \hline Cnf \\ 481 \\ 1981 \\ 3156 \\ 4524 \\ 6052 \\ 11893 \end{array}$	$\begin{array}{c} 456.3 \text{s} \\ \textbf{perty} \\ \hline T^{sol} \\ 0.1 \text{s} \\ 0.2 \text{s} \end{array}$	Var           176           607           877           1147           1447	$\begin{array}{c} M_{sim} \\ \hline \\ Cnf \\ 465 \\ 1918 \\ 2934 \\ 3950 \\ 4966 \\ 9251 \end{array}$	$\begin{array}{c} 237.3 \\ \hline T^{sol} \\ 0.1s \\ 0.1s \\ 0.1s \\ 0.1s \\ 0.1s \\ 0.2s \end{array}$
$\begin{array}{c} \text{Round} \\ \hline 1 \\ \hline 2 \\ \hline 3 \\ \hline 4 \\ \hline 5 \\ \hline 6 \\ \hline 7 \\ \end{array}$	log <sub>2</sub> Cor <sub>opt</sub> 0 -1 -2 -3 -4 -6 -8	7765375 Lir Var 176 623 1013 1499 2081 4353 6051	$\begin{array}{c} 7187757\\ \hline \textbf{near Pro}\\ \hline M_{sun}\\ \hline Cnf\\ 481\\ 1981\\ 3156\\ 4524\\ 6052\\ 11893\\ 15376\\ \end{array}$	$\begin{array}{c} 456.3 \text{s} \\ \textbf{perty} \\ \hline T^{sol} \\ 0.1 \text{s} \\ 0.2 \text{s} \\ 0.3 \text{s} \\ \end{array}$	$\begin{array}{r} 1460479\\ \hline \\ Var\\ 176\\ 607\\ 877\\ 1147\\ 1417\\ 2671\\ 3331 \end{array}$	$\begin{array}{c} M_{sim} \\ \hline M_{sim} \\ \hline Cnf \\ 465 \\ 1918 \\ 2934 \\ 3950 \\ 4966 \\ 9251 \\ 11279 \end{array}$	$\begin{array}{c} 237.3 \\ \hline T^{sol} \\ 0.1s \\ 0.1s \\ 0.1s \\ 0.1s \\ 0.2s \\ 0.3s \\ \end{array}$
$\begin{array}{c} \text{Round} \\ \hline 1 \\ \hline 2 \\ \hline 3 \\ \hline 4 \\ \hline 5 \\ \hline 6 \\ \hline 7 \\ \hline 8 \\ \end{array}$	log <sub>2</sub> Cor <sub>opt</sub> 0 -1 -2 -3 -4 -6 -8 -11	7765375 Lir Var 176 623 1013 1499 2081 4353 6051 11098	$\begin{array}{c} 7187757\\ \hline \textbf{near Pro}\\ \hline M_{sun}\\ \hline Cnf\\ 481\\ 1981\\ 3156\\ 4524\\ 6052\\ 11893\\ 15376\\ 26227\\ \end{array}$	$\begin{array}{c} 456.3 \mathrm{s} \\ \mathbf{perty} \\ \hline T^{sol} \\ 0.1 \mathrm{s} \\ 0.2 \mathrm{s} \\ 0.3 \mathrm{s} \\ 0.5 \mathrm{s} \end{array}$	$\begin{array}{r} 1460479\\ \hline \\ Var\\ 176\\ 607\\ 877\\ 1147\\ 1417\\ 2671\\ 3331\\ 5570\\ \end{array}$	$\frac{M_{sim}}{Cnf}\\ \frac{465}{1918}\\ \frac{2934}{3950}\\ \frac{4966}{9251}\\ 111279\\ 18236$	$\begin{array}{c} 237.3 \\ \hline T^{sol} \\ 0.1s \\ 0.1s \\ 0.1s \\ 0.1s \\ 0.2s \\ 0.3s \\ 0.5s \end{array}$
Round 1 2 3 4 5 6 7 8 9	$\begin{array}{c} \log_2 Cor_{opt} \\ 0 \\ -1 \\ -2 \\ -3 \\ -4 \\ -6 \\ -8 \\ -11 \\ -14 \end{array}$	7765375 Lin Var 176 623 1013 1499 2081 4353 6051 11098 15038	$\begin{array}{c} 7187757\\ \textbf{near Pro}\\ M_{sun}\\ Cnf\\ 481\\ 1981\\ 3156\\ 4524\\ 6052\\ 11893\\ 15376\\ 26227\\ 33227\\ \end{array}$	$\begin{array}{c} 456.3 \mathrm{s} \\ \mathbf{perty} \\ \hline T^{sol} \\ 0.1 \mathrm{s} \\ 0.2 \mathrm{s} \\ 0.3 \mathrm{s} \\ 0.5 \mathrm{s} \\ 0.8 \mathrm{s} \end{array}$	$\begin{array}{c} 1460479\\ \hline \\ Var\\ 176\\ 607\\ 877\\ 1147\\ 1417\\ 2671\\ 3331\\ 5570\\ 6910\\ \end{array}$	$\frac{M_{sim}}{Cnf}$ $\frac{Cnf}{465}$ $\frac{465}{1918}$ $\frac{2934}{3950}$ $\frac{4966}{9251}$ $11279$ $18236$ $21852$	$\begin{array}{c} 237.3 \\ \hline T^{sol} \\ 0.1s \\ 0.1s \\ 0.1s \\ 0.1s \\ 0.2s \\ 0.3s \\ 0.5s \\ 0.8s \end{array}$
Round 1 2 3 4 5 6 7 8 9 10	log <sub>2</sub> Cor <sub>opt</sub> 0 -1 -2 -3 -4 -6 -8 -11 -14 -18	7765375 Lin Var 176 623 1013 1499 2081 4353 6051 11098 15038 25040	$\begin{array}{c} 7187757\\ \hline \textbf{near Pro}\\ \hline M_{sun}\\ \hline Cnf\\ 481\\ 3156\\ 4524\\ 6052\\ 11893\\ 15376\\ 26227\\ 33227\\ 52116\\ \end{array}$	$\begin{array}{c} 456.3 \text{s} \\ \textbf{perty} \\ \hline T^{sol} \\ 0.1 \text{s} \\ 0.2 \text{s} \\ 0.3 \text{s} \\ 0.3 \text{s} \\ 0.3 \text{s} \\ 0.4 \text{s} \\ 1.4 \text{s} \end{array}$	$\begin{array}{c} 1460479\\ \hline\\ Var\\ 176\\ 607\\ 877\\ 1147\\ 1417\\ 2671\\ 3331\\ 5570\\ 6910\\ 10700\\ \end{array}$	$\frac{M_{sim}}{Cnf}\\ \frac{Cnf}{465}\\ 1918\\ 2934\\ 3950\\ 4966\\ 9251\\ 11279\\ 18236\\ 21852\\ 32605\\ \end{array}$	$\begin{array}{c} T^{sol} \\ 0.1s \\ 0.1s \\ 0.1s \\ 0.1s \\ 0.1s \\ 0.2s \\ 0.3s \\ 0.5s \\ 0.8s \\ 1.3s \end{array}$
Round 1 2 3 4 5 6 7 8 9 10 11	log <sub>2</sub> Cor <sub>opt</sub> 0 -1 -2 -3 -4 -6 -8 -11 -14 -18 -22	$\begin{array}{c} 7765375\\ {\color{black} {\rm Lir}}\\ \hline \\ Var\\ 176\\ 623\\ 1013\\ 1499\\ 2081\\ 4353\\ 6051\\ 11098\\ 15038\\ 15038\\ 25040\\ 32780\\ \end{array}$	$\begin{array}{c} 7187757\\ \textbf{Hear Processor}\\ \hline M_{sum} & Cnf\\ 481\\ 1981\\ 3156\\ 4524\\ 6052\\ 11893\\ 15376\\ 26227\\ 33227\\ 52116\\ 64771\\ \end{array}$	$\begin{array}{c} 456.3 \mathrm{s} \\ \mathbf{perty} \\ \hline T^{sol} \\ 0.1 \mathrm{s} \\ 0.2 \mathrm{s} \\ 0.3 \mathrm{s} \\ 0.3 \mathrm{s} \\ 0.3 \mathrm{s} \\ 0.5 \mathrm{s} \\ 0.8 \mathrm{s} \\ 1.4 \mathrm{s} \\ 2.6 \mathrm{s} \end{array}$	$\begin{array}{c} 1460479\\ \hline\\ Var\\ 176\\ 607\\ 877\\ 1147\\ 1417\\ 2671\\ 3331\\ 5570\\ 6910\\ 10700\\ 13100\\ \end{array}$	$\frac{M_{sim}}{Cnf}$ $\frac{Cnf}{465}$ 1918 2934 3950 4966 9251 11279 18236 21852 32605 38565	$\begin{array}{c} 237.3 \\ \hline T^{sol} \\ 0.1s \\ 0.1s \\ 0.1s \\ 0.1s \\ 0.2s \\ 0.3s \\ 0.5s \\ 0.8s \\ 1.3s \\ 2.2s \end{array}$
$\begin{array}{c} \text{Round} \\ \hline 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \\ 9 \\ 10 \\ 11 \\ 12 \\ \end{array}$	log <sub>2</sub> Cor <sub>opt</sub> 0 -1 -2 -3 -4 -6 -8 -11 -14 -18 -22 -24	7765375 Lin Var 176 623 1013 1499 2081 4353 6051 11098 15038 25040 32780 24027	$\begin{array}{c} 7187757\\ \hline \textbf{near Pro}\\ \hline M_{sun}\\ \hline Cnf\\ 481\\ 1981\\ 3156\\ 4524\\ 6052\\ 11893\\ 15376\\ 26227\\ 33227\\ 52116\\ 64771\\ 46129\\ \end{array}$	$\begin{array}{c} 456.3{\rm s}\\ {\bf perty}\\ \hline T^{sol}\\ 0.1{\rm s}\\ 0.1{\rm s}\\ 0.1{\rm s}\\ 0.1{\rm s}\\ 0.1{\rm s}\\ 0.2{\rm s}\\ 0.3{\rm s}\\ 0.3{\rm s}\\ 0.5{\rm s}\\ 1.4{\rm s}\\ 2.6{\rm s}\\ 1.3{\rm s}\\ \end{array}$	$\begin{array}{c} 1460479\\ \hline\\ Var\\ 176\\ 607\\ 877\\ 1147\\ 1417\\ 1417\\ 2671\\ 3331\\ 5570\\ 6910\\ 10700\\ 103100\\ 8737\\ \end{array}$	$\frac{M_{sim}}{Cnf}$ $\frac{Cnf}{465}$ 1918 2934 3950 4966 9251 11279 18236 21852 32605 25595	$\begin{array}{c} 237.3 \\ \hline T^{sol} \\ 0.1s \\ 0.1s \\ 0.1s \\ 0.1s \\ 0.2s \\ 0.3s \\ 0.3s \\ 0.5s \\ 0.8s \\ 1.3s \\ 2.2s \\ 1.2s \end{array}$
$\begin{array}{c} \text{Round} \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \\ 9 \\ 10 \\ 11 \\ 12 \\ 13 \\ \end{array}$	$\begin{array}{c} \log_2 Cor_{opt} \\ 0 \\ -1 \\ -2 \\ -3 \\ -4 \\ -6 \\ -8 \\ -11 \\ -14 \\ -18 \\ -22 \\ -22 \\ -24 \\ -27 \end{array}$	7765375 Lin Var 176 623 1013 1499 2081 4353 6051 11098 15038 25040 32780 24027 37802	$\begin{array}{c} 7187757\\ \hline \textbf{near Pro}\\ \hline M_{sun}\\ \hline Cnf\\ 481\\ 1981\\ 3156\\ 4524\\ 6052\\ 11893\\ 15376\\ 26227\\ 33227\\ 52116\\ 64771\\ 46129\\ 71199\\ \end{array}$	$\begin{array}{c} 456.3{\rm s}\\ {\bf perty}\\ \hline T^{sol}\\ 0.1{\rm s}\\ 0.1{\rm s}\\ 0.1{\rm s}\\ 0.1{\rm s}\\ 0.1{\rm s}\\ 0.2{\rm s}\\ 0.3{\rm s}\\ 0.3{\rm s}\\ 0.5{\rm s}\\ 0.4{\rm s}\\ 1.4{\rm s}\\ 2.6{\rm s}\\ 1.3{\rm s}\\ 3.2{\rm s}\\ \end{array}$	$\begin{array}{c} 1460479\\ \hline\\ Var\\ 176\\ 607\\ 877\\ 1147\\ 1417\\ 2671\\ 3331\\ 5570\\ 6910\\ 10700\\ 13100\\ 8737\\ 12554 \end{array}$	$\begin{array}{c} M_{sim} \\ \hline Cnf \\ 465 \\ 1918 \\ 2934 \\ 3950 \\ 4966 \\ 9251 \\ 11279 \\ 18236 \\ 21852 \\ 32605 \\ 38565 \\ 25595 \\ 36876 \end{array}$	$\begin{array}{c} T^{sol} \\ 0.1s \\ 0.1s \\ 0.1s \\ 0.1s \\ 0.1s \\ 0.2s \\ 0.2s \\ 0.5s \\ 0.8s \\ 1.3s \\ 2.2s \\ 1.2s \\ 2.3s \end{array}$
Round 1 2 3 4 5 6 7 8 9 10 11 12 13 14	$\begin{array}{c} \log_2 Cor_{opt} \\ 0 \\ -1 \\ -2 \\ -3 \\ -4 \\ -6 \\ -8 \\ -11 \\ -14 \\ -18 \\ -22 \\ -22 \\ -27 \\ -30 \\ \end{array}$	7765375 Lin Var 176 623 1013 1499 2081 4353 6051 11098 15038 25040 32780 24027 37802 44718	$\begin{array}{c} 7187757\\ \hline \textbf{near Pro}\\ \hline M_{sun}\\ \hline Cnf\\ 481\\ 1981\\ 3156\\ 4524\\ 6052\\ 11893\\ 15376\\ 26227\\ 33227\\ 52116\\ 64771\\ 46129\\ 71199\\ 82487\\ \end{array}$	$\begin{array}{c} 456.3 \mathrm{s} \\ perty \\ \hline T^{sol} \\ 0.1 \mathrm{s} \\ 0.2 \mathrm{s} \\ 0.3 \mathrm{s} \\ 0.3 \mathrm{s} \\ 0.3 \mathrm{s} \\ 1.4 \mathrm{s} \\ 2.6 \mathrm{s} \\ 1.3 \mathrm{s} \\ 1.3 \mathrm{s} \\ 2.8 \mathrm{s} \end{array}$	$\begin{array}{c} 1460479\\ \hline\\ Var\\ 176\\ 607\\ 877\\ 1147\\ 1417\\ 2671\\ 5570\\ 6910\\ 10700\\ 13100\\ 8737\\ 12554\\ 13830\\ \end{array}$	$\begin{array}{c} M_{sim} \\ Cnf \\ 465 \\ 1918 \\ 2934 \\ 3950 \\ 4966 \\ 9251 \\ 11279 \\ 18236 \\ 21852 \\ 32605 \\ 38565 \\ 25595 \\ 36876 \\ 40364 \end{array}$	$\begin{array}{c} T^{sol} \\ 0.1s \\ 0.1s \\ 0.1s \\ 0.1s \\ 0.2s \\ 0.2s \\ 0.5s \\ 0.8s \\ 1.3s \\ 2.2s \\ 1.2s \\ 2.3s \\ 1.9s \end{array}$
$\begin{array}{c} \text{Round} \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \\ 9 \\ 10 \\ 11 \\ 12 \\ 13 \\ 14 \\ 15 \\ \end{array}$	$\begin{array}{c} \log_2 Cor_{opt} \\ \hline 0 \\ -1 \\ -2 \\ -3 \\ -4 \\ -6 \\ -8 \\ -11 \\ -14 \\ -18 \\ -22 \\ -24 \\ -27 \\ -30 \\ -33 \\ \end{array}$	7765375 <i>Var</i> 176 623 1013 1499 2081 4353 6051 11098 15038 25040 32780 24027 37802 24027 37802 244718 52210	$\begin{array}{c} 7187757\\ \hline \textbf{near Pro}\\ \hline M_{sun}\\ \hline Cnf\\ 481\\ 1981\\ 3156\\ 4524\\ 6052\\ 11893\\ 15376\\ 26227\\ 33227\\ 52116\\ 64771\\ 46129\\ 71199\\ 82487\\ 94607\\ \end{array}$	$\begin{array}{c} 456.3 \mathrm{s} \\ \mathbf{pperty} \\ \hline T^{sol} \\ 0.1 \mathrm{s} \\ 0.2 \mathrm{s} \\ 0.3 \mathrm{s} \\ 0.4 \mathrm{s} \\ 2.6 \mathrm{s} \\ 1.4 \mathrm{s} \\ 2.6 \mathrm{s} \\ 1.4 \mathrm{s} \\ 2.6 \mathrm{s} \\ 3.2 \mathrm{s} \\ 2.8 \mathrm{s} \\ 3.7 \mathrm{s} \end{array}$	1460479 Var 176 607 877 1147 1417 2671 3331 5570 6910 10700 10700 10700 8737 12554 13830 15106	$\frac{M_{sim}}{Cnf}$ $\frac{A65}{1918}$ $\frac{2934}{3950}$ $\frac{3950}{4966}$ $\frac{9251}{11279}$ $18236$ $\frac{21852}{32605}$ $\frac{38565}{25595}$ $\frac{36876}{40364}$ $\frac{40364}{43852}$	$\begin{array}{c} 237.3\\ \hline T^{sol}\\ 0.1s\\ 0.1s\\ 0.1s\\ 0.1s\\ 0.2s\\ 0.3s\\ 0.5s\\ 0.8s\\ 1.3s\\ 2.2s\\ 1.2s\\ 1.2s\\ 2.3s\\ 1.9s\\ 3.5s\end{array}$
$\begin{array}{c} \text{Round} \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \\ 9 \\ 10 \\ 11 \\ 12 \\ 13 \\ 14 \\ 15 \\ 16 \\ \end{array}$	$\begin{array}{c} \log_2 Cor_{opt} \\ \hline 0 \\ -1 \\ -2 \\ -3 \\ -4 \\ -6 \\ -8 \\ -11 \\ -14 \\ -18 \\ -22 \\ -24 \\ -27 \\ -30 \\ -33 \\ -36 \\ \end{array}$	7765375 Lin Var 176 623 1013 1499 2081 4353 6051 11098 15038 25040 32780 24027 37802 24027 37802 44718 52210 60278	$\begin{array}{c} 7187757\\ \hline \textbf{Hear Processor}\\ \hline M_{sum} & Cnf\\ 481\\ 1981\\ 3156\\ 4524\\ 6052\\ 11893\\ 15376\\ 26227\\ 33227\\ 52116\\ 64771\\ 46129\\ 71199\\ 82487\\ 71199\\ 82487\\ 94607\\ 107559 \end{array}$	$\begin{array}{c} 456.3 \mathrm{s} \\ \hline \\ T^{sol} \\ 0.1 \mathrm{s} \\ 0.2 \mathrm{s} \\ 0.3 \mathrm{s} \\ 0.3 \mathrm{s} \\ 0.3 \mathrm{s} \\ 1.4 \mathrm{s} \\ 2.6 \mathrm{s} \\ 1.3 \mathrm{s} \\ 3.2 \mathrm{s} \\ 2.8 \mathrm{s} \\ 3.7 \mathrm{s} \\ 7.8 \mathrm{s} \end{array}$	$\begin{array}{c} 1460479\\ \hline\\ & Var\\ 176\\ 607\\ 877\\ 1147\\ 2671\\ 3331\\ 5570\\ 6910\\ 10700\\ 13100\\ 8737\\ 12554\\ 13830\\ 13830\\ 15106\\ 16382 \end{array}$	$\begin{array}{c} 3772758\\ \hline M_{sim}\\ \hline Cnf\\ 465\\ 1918\\ 2934\\ 3950\\ 9251\\ 11279\\ 18236\\ 21852\\ 32605\\ 32505\\ 32595\\ 338565\\ 25595\\ 36876\\ 40364\\ 43852\\ 47340\\ \end{array}$	$\begin{array}{c} 237.3 \\ \hline T^{sol} \\ 0.1s \\ 0.1s \\ 0.1s \\ 0.1s \\ 0.2s \\ 0.3s \\ 0.5s \\ 0.8s \\ 1.3s \\ 2.2s \\ 1.2s \\ 2.3s \\ 1.9s \\ 3.5s \\ 3.7s \end{array}$
$\begin{array}{c} \text{Round} \\ \hline 1 \\ \hline 2 \\ \hline 3 \\ \hline 4 \\ \hline 5 \\ \hline 6 \\ \hline 7 \\ \hline 8 \\ 9 \\ \hline 10 \\ \hline 11 \\ \hline 12 \\ \hline 13 \\ \hline 14 \\ \hline 15 \\ \hline 16 \\ \hline 17 \\ \end{array}$	$\begin{array}{c} \log_2 Cor_{opt} \\ \hline 0 \\ -1 \\ -2 \\ -3 \\ -4 \\ -6 \\ -8 \\ -11 \\ -14 \\ -18 \\ -22 \\ -24 \\ -27 \\ -30 \\ -33 \\ -36 \\ -37 \\ \end{array}$	7765375 Lin Var 176 623 1013 1499 2081 4353 6051 11098 4353 6051 11098 15038 25040 24027 37802 24027 37802 24027 37802 44718 52210 60278 33647	$\begin{array}{c} 7187757\\ \hline \textbf{near Proc}\\ \hline M_{sun}\\ \hline Cnf\\ 481\\ 1981\\ 3156\\ 4524\\ 6052\\ 11893\\ 15376\\ 26227\\ 33227\\ 52116\\ 64771\\ 46129\\ 71199\\ 82487\\ 94607\\ 107559\\ 59590\\ \end{array}$	$\begin{array}{r} 456.3 \mathrm{s} \\ \hline T^{sol} \\ 0.1 \mathrm{s} \\ 0.2 \mathrm{s} \\ 0.3 \mathrm{s} \\ 0.5 \mathrm{s} \\ 0.3 \mathrm{s} \\ 0.4 \mathrm{s} \\ 1.4 \mathrm{s} \\ 2.6 \mathrm{s} \\ 1.3 \mathrm{s} \\ 3.2 \mathrm{s} \\ 3.2 \mathrm{s} \\ 3.7 \mathrm{s} \\ 7.8 \mathrm{s} \\ 2.5 \mathrm{s} \end{array}$	$\begin{array}{c} 1460479\\ \hline\\ Var\\ 176\\ 607\\ 877\\ 1147\\ 1417\\ 2671\\ 3331\\ 5570\\ 6910\\ 10700\\ 8737\\ 12554\\ 13830\\ 15106\\ 16382\\ 8291 \end{array}$	$\begin{array}{c} M_{sim} \\ Cnf \\ 465 \\ 1918 \\ 2934 \\ 3950 \\ 4966 \\ 9251 \\ 11279 \\ 18236 \\ 21852 \\ 32605 \\ 25595 \\ 38565 \\ 25595 \\ 36876 \\ 40364 \\ 43852 \\ 47340 \\ 24342 \\ \end{array}$	$\begin{array}{c} 237.3\\ \hline T^{sol}\\ 0.1s\\ 0.1s\\ 0.1s\\ 0.1s\\ 0.1s\\ 0.2s\\ 0.3s\\ 1.2s\\ 2.2s\\ 1.2s\\ 2.3s\\ 1.2s\\ 2.3s\\ 1.9s\\ 3.5s\\ 3.7s\\ 1.7s\end{array}$
$\begin{array}{c} \text{Round} \\ \hline 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \\ 9 \\ 10 \\ 11 \\ 12 \\ 13 \\ 14 \\ 15 \\ 16 \\ 17 \\ 18 \\ \end{array}$	$\begin{array}{c} \log_2 Cor_{opt} \\ \hline 0 \\ -1 \\ -2 \\ -3 \\ -4 \\ -6 \\ -8 \\ -11 \\ -14 \\ -18 \\ -22 \\ -24 \\ -27 \\ -30 \\ -33 \\ -36 \\ -37 \\ -40 \\ \end{array}$	7765375 Lin Var 176 623 1013 1499 2081 4353 6051 11098 15038 25040 32780 24027 37802 44718 52210 60278 33647 74694	$\begin{array}{r} 7187757\\ \hline \textbf{near Pro}\\ \hline M_{sun} & Cnf\\ \hline A81\\ 1981\\ 3156\\ 4524\\ 6052\\ 11893\\ 15376\\ 26227\\ 33227\\ 52116\\ 64771\\ 46129\\ 71199\\ 82487\\ 94607\\ 107559\\ 959590\\ 131375 \end{array}$	$\begin{array}{r} 456.3 \mathrm{s} \\ \hline T^{sol} \\ 0.1 \mathrm{s} \\ 0.2 \mathrm{s} \\ 0.3 \mathrm{s} \\ 0.3 \mathrm{s} \\ 0.4 \mathrm{s} \\ 1.4 \mathrm{s} \\ 2.6 \mathrm{s} \\ 1.3 \mathrm{s} \\ 3.2 \mathrm{s} \\ 2.8 \mathrm{s} \\ 3.7 \mathrm{s} \\ 7.8 \mathrm{s} \\ 2.5 \mathrm{s} \\ 4.2 \mathrm{s} \end{array}$	$\begin{array}{c} 1460479\\ \hline\\ Var\\ 176\\ 607\\ 877\\ 1147\\ 1417\\ 2671\\ 3331\\ 5570\\ 6910\\ 10700\\ 13300\\ 8737\\ 12554\\ 13830\\ 15106\\ 16382\\ 8291\\ 16918\\ \end{array}$	$\begin{array}{c} M_{sim} \\ \hline Cnf \\ 465 \\ 1918 \\ 2934 \\ 3950 \\ 4966 \\ 9251 \\ 11279 \\ 18236 \\ 21852 \\ 32605 \\ 338565 \\ 25595 \\ 36876 \\ 40364 \\ 43852 \\ 47340 \\ 47340 \\ 24342 \\ 50300 \\ \end{array}$	$\begin{array}{c} 237.3\\ \hline T^{sol}\\ 0.1s\\ 0.1s\\ 0.1s\\ 0.2s\\ 0.3s\\ 0.2s\\ 0.3s\\ 0.2s\\ 0.3s\\ 1.3s\\ 2.2s\\ 1.2s\\ 2.3s\\ 1.9s\\ 3.7s\\ 1.7s\\ 2.4s\end{array}$
$\begin{array}{c} \text{Round} \\ \hline 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \\ 9 \\ 10 \\ 11 \\ 12 \\ 13 \\ 14 \\ 15 \\ 16 \\ 17 \\ 18 \\ 19 \\ \end{array}$	$\begin{array}{c} \log_2 Cor_{opt} \\ 0 \\ -1 \\ -2 \\ -3 \\ -4 \\ -6 \\ -8 \\ -11 \\ -14 \\ -18 \\ -22 \\ -24 \\ -27 \\ -30 \\ -33 \\ -36 \\ -37 \\ -40 \\ -42 \\ \end{array}$	7765375 Lin Var 176 623 1013 1499 2081 4353 6051 11098 15038 25040 32780 24027 37802 44718 52210 60278 33647 74694 62541	$\begin{array}{c} 7187757\\ \hline \textbf{near Pro}\\ \hline M_{sun} \\ \hline Cnf \\ 481 \\ 1981 \\ 3156 \\ 4524 \\ 6052 \\ 11893 \\ 15376 \\ 26227 \\ 33227 \\ 52116 \\ 64771 \\ 46129 \\ 71199 \\ 82487 \\ 94607 \\ 107559 \\ 59590 \\ 131375 \\ 109018 \end{array}$	$\begin{array}{r} 456.3 \mathrm{s} \\ \hline perty \\ \hline T^{sol} \\ 0.1 \mathrm{s} \\ 0.2 \mathrm{s} \\ 0.3 \mathrm{s} \\ 0.3 \mathrm{s} \\ 0.3 \mathrm{s} \\ 1.4 \mathrm{s} \\ 2.6 \mathrm{s} \\ 1.3 \mathrm{s} \\ 3.2 \mathrm{s} \\ 2.8 \mathrm{s} \\ 3.7 \mathrm{s} \\ 7.8 \mathrm{s} \\ 2.5 \mathrm{s} \\ 4.2 \mathrm{s} \\ 3.4 \mathrm{s} \end{array}$	$\begin{array}{c} 1460479\\ \hline\\ Var\\ 176\\ 607\\ 877\\ 1147\\ 1417\\ 2671\\ 3331\\ 5570\\ 6910\\ 10700\\ 13100\\ 8737\\ 12554\\ 13830\\ 15106\\ 16382\\ 8291\\ 16918\\ 13291\\ \end{array}$	$\begin{array}{c} M_{sim} \\ \hline \\ Cnf \\ 465 \\ 1918 \\ 2934 \\ 3950 \\ 4966 \\ 9251 \\ 11279 \\ 18236 \\ 21852 \\ 32605 \\ 32605 \\ 32655 \\ 32655 \\ 325595 \\ 36876 \\ 40364 \\ 43852 \\ 47340 \\ 24342 \\ 50300 \\ 39635 \\ \end{array}$	$\begin{array}{c} 237.3\\ \hline T^{sol}\\ 0.1s\\ 0.1s\\ 0.1s\\ 0.2s\\ 0.3s\\ 0.2s\\ 0.2s\\$
$\begin{array}{c} \text{Round} \\ \hline 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \\ 9 \\ 10 \\ 11 \\ 12 \\ 13 \\ 14 \\ 15 \\ 16 \\ 17 \\ 18 \\ \end{array}$	$\begin{array}{c} \log_2 Cor_{opt} \\ \hline 0 \\ -1 \\ -2 \\ -3 \\ -4 \\ -6 \\ -8 \\ -11 \\ -14 \\ -18 \\ -22 \\ -24 \\ -27 \\ -30 \\ -33 \\ -36 \\ -37 \\ -40 \\ \end{array}$	7765375 Lin Var 1776 623 1013 1499 2081 4353 6051 11098 15038 25040 32780 24027 37802 44718 52210 60278 33647 74694 92562	$\begin{array}{c} 7187757\\ \hline \textbf{near Pro}\\ \hline M_{sun}\\ \hline Cnf\\ 481\\ 1981\\ 3156\\ 4524\\ 6052\\ 11893\\ 15376\\ 26227\\ 33227\\ 52116\\ 64771\\ 46129\\ 82487\\ 94607\\ 107559\\ 94607\\ 107559\\ 959500\\ 131375\\ 109018\\ 160043\\ \end{array}$	$\begin{array}{r} 456.3 \mathrm{s} \\ perty \\ \hline T^{sol} \\ 0.1 \mathrm{s} \\ 0.2 \mathrm{s} \\ 0.3 \mathrm{s} \\ 0.3 \mathrm{s} \\ 0.3 \mathrm{s} \\ 0.3 \mathrm{s} \\ 1.4 \mathrm{s} \\ 2.6 \mathrm{s} \\ 1.3 \mathrm{s} \\ 1.3 \mathrm{s} \\ 3.2 \mathrm{s} \\ 2.8 \mathrm{s} \\ 3.7 \mathrm{s} \\ 7.8 \mathrm{s} \\ 2.5 \mathrm{s} \\ 4.2 \mathrm{s} \\ 3.4 \mathrm{s} \\ 4.3 \mathrm{s} \end{array}$	$\begin{array}{c} 1460479\\ \hline\\ Var\\ 176\\ 607\\ 877\\ 1147\\ 1417\\ 2671\\ 3331\\ 5570\\ 6910\\ 10700\\ 13300\\ 8737\\ 12554\\ 13830\\ 15106\\ 16382\\ 8291\\ 16918\\ \end{array}$	$\begin{array}{r} \frac{M_{sim}}{Cnf} \\ \frac{Cnf}{2} \\ \frac{465}{1918} \\ 2934 \\ 3950 \\ 4966 \\ 9251 \\ 11279 \\ 18236 \\ 21852 \\ 32605 \\ 33565 \\ 25595 \\ 36876 \\ 40364 \\ 43852 \\ 47340 \\ 24342 \\ 50300 \\ 24342 \\ 503035 \\ 55532 \\ \end{array}$	$\begin{array}{c} 237.3\\ \hline T^{sol}\\ 0.1s\\ 0.1s\\ 0.1s\\ 0.1s\\ 0.2s\\ 0.3s\\ 0.2s\\ 0.3s\\ 0.3s\\$
$\begin{array}{c} \text{Round} \\ \hline 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \\ 9 \\ 10 \\ 11 \\ 12 \\ 13 \\ 14 \\ 15 \\ 16 \\ 17 \\ 18 \\ 19 \\ \end{array}$	$\begin{array}{c} \log_2 Cor_{opt} \\ 0 \\ -1 \\ -2 \\ -3 \\ -4 \\ -6 \\ -8 \\ -11 \\ -14 \\ -18 \\ -22 \\ -24 \\ -27 \\ -30 \\ -33 \\ -36 \\ -37 \\ -40 \\ -42 \\ \end{array}$	7765375 Lin Var 176 623 1013 1499 2081 4353 6051 11098 15038 25040 32780 24027 37802 44718 52210 60278 33647 74694 62541	$\begin{array}{c} 7187757\\ \hline \textbf{near Pro}\\ \hline M_{sun} \\ \hline Cnf \\ 481 \\ 1981 \\ 3156 \\ 4524 \\ 6052 \\ 11893 \\ 15376 \\ 26227 \\ 33227 \\ 52116 \\ 64771 \\ 46129 \\ 71199 \\ 82487 \\ 94607 \\ 107559 \\ 59590 \\ 131375 \\ 109018 \end{array}$	$\begin{array}{r} 456.3 \mathrm{s} \\ \hline perty \\ \hline T^{sol} \\ 0.1 \mathrm{s} \\ 0.2 \mathrm{s} \\ 0.3 \mathrm{s} \\ 0.3 \mathrm{s} \\ 0.3 \mathrm{s} \\ 1.4 \mathrm{s} \\ 2.6 \mathrm{s} \\ 1.3 \mathrm{s} \\ 3.2 \mathrm{s} \\ 2.8 \mathrm{s} \\ 3.7 \mathrm{s} \\ 7.8 \mathrm{s} \\ 2.5 \mathrm{s} \\ 4.2 \mathrm{s} \\ 3.4 \mathrm{s} \end{array}$	$\begin{array}{c} 1460479\\ \hline\\ & Var\\ 176\\ 607\\ 877\\ 1147\\ 2671\\ 3331\\ 5570\\ 6910\\ 13331\\ 5570\\ 10700\\ 13100\\ 8737\\ 12554\\ 13830\\ 15106\\ 16382\\ 8291\\ 13830\\ 15106\\ 16382\\ 8291\\ 16918\\ 13291\\ 18594\\ 14548\\ \end{array}$	$\begin{array}{c} M_{sim} \\ \hline \\ Cnf \\ 465 \\ 1918 \\ 2934 \\ 3950 \\ 4966 \\ 9251 \\ 11279 \\ 18236 \\ 21852 \\ 32605 \\ 32605 \\ 32655 \\ 32655 \\ 325595 \\ 36876 \\ 40364 \\ 43852 \\ 47340 \\ 24342 \\ 50300 \\ 39635 \\ \end{array}$	$\begin{array}{c} 237.3\\ \hline T^{sol}\\ 0.1s\\ 0.1s\\ 0.1s\\ 0.2s\\ 0.3s\\ 0.2s\\ 0.2s\\$
$\begin{array}{c} \text{Round} \\ \hline 1 \\ 2 \\ \hline 3 \\ 4 \\ 5 \\ \hline 6 \\ 7 \\ 7 \\ 8 \\ 9 \\ 10 \\ 11 \\ 12 \\ 13 \\ 14 \\ 15 \\ 16 \\ 17 \\ 18 \\ 19 \\ 20 \\ \end{array}$	$\begin{array}{c} \log_2 Cor_{opt} \\ \hline 0 \\ -1 \\ -2 \\ -3 \\ -4 \\ -6 \\ -8 \\ -11 \\ -14 \\ -18 \\ -22 \\ -27 \\ -30 \\ -33 \\ -36 \\ -37 \\ -40 \\ -42 \\ -45 \\ \end{array}$	7765375 Lin Var 1776 623 1013 1499 2081 4353 6051 11098 15038 25040 32780 24027 37802 44718 52210 60278 33647 74694 92562	$\begin{array}{c} 7187757\\ \hline \textbf{near Pro}\\ \hline M_{sun}\\ \hline Cnf\\ 481\\ 1981\\ 3156\\ 4524\\ 6052\\ 11893\\ 15376\\ 26227\\ 33227\\ 52116\\ 64771\\ 46129\\ 82487\\ 94607\\ 107559\\ 94607\\ 107559\\ 959500\\ 131375\\ 109018\\ 160043\\ \end{array}$	$\begin{array}{r} 456.3 \mathrm{s} \\ perty \\ \hline T^{sol} \\ 0.1 \mathrm{s} \\ 0.2 \mathrm{s} \\ 0.3 \mathrm{s} \\ 0.3 \mathrm{s} \\ 0.3 \mathrm{s} \\ 0.3 \mathrm{s} \\ 1.4 \mathrm{s} \\ 2.6 \mathrm{s} \\ 1.3 \mathrm{s} \\ 1.3 \mathrm{s} \\ 3.2 \mathrm{s} \\ 2.8 \mathrm{s} \\ 3.7 \mathrm{s} \\ 7.8 \mathrm{s} \\ 2.5 \mathrm{s} \\ 4.2 \mathrm{s} \\ 3.4 \mathrm{s} \\ 4.3 \mathrm{s} \end{array}$	$\begin{array}{c} 1460479\\ \hline\\ Var\\ 176\\ 607\\ 877\\ 1147\\ 1417\\ 2671\\ 3331\\ 5570\\ 6910\\ 10700\\ 13100\\ 8737\\ 12554\\ 13830\\ 15106\\ 16382\\ 8291\\ 15106\\ 16318\\ 13291\\ 18594\\ \end{array}$	$\begin{array}{r} \frac{M_{sim}}{Cnf} \\ \frac{Cnf}{2} \\ \frac{465}{1918} \\ 2934 \\ 3950 \\ 4966 \\ 9251 \\ 11279 \\ 18236 \\ 21852 \\ 32605 \\ 33565 \\ 25595 \\ 36876 \\ 40364 \\ 43852 \\ 47340 \\ 24342 \\ 50300 \\ 24342 \\ 503035 \\ 55532 \\ \end{array}$	$\begin{array}{c} 237.3\\ \hline T^{sol}\\ 0.1s\\ 0.1s\\ 0.1s\\ 0.1s\\ 0.2s\\ 0.3s\\ 0.2s\\ 0.3s\\ 0.3s\\$
$\begin{array}{c} \text{Round} \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \\ 9 \\ 10 \\ 11 \\ 12 \\ 13 \\ 14 \\ 15 \\ 16 \\ 17 \\ 18 \\ 19 \\ 20 \\ 21 \\ \end{array}$	$\begin{array}{c} \log_2 Cor_{opt} \\ \hline 0 \\ -1 \\ -2 \\ -3 \\ -4 \\ -6 \\ -8 \\ -11 \\ -14 \\ -18 \\ -22 \\ -24 \\ -27 \\ -30 \\ -33 \\ -36 \\ -37 \\ -40 \\ -42 \\ -45 \\ -47 \\ \end{array}$	7765375 Lin Var 176 623 1013 1499 2081 4353 6051 11098 15038 25040 32780 24027 37802 44718 52210 60278 33647 74694 62541 92562 76662	$\begin{array}{c} 7187757\\ \hline \textbf{rear Pro}\\ \hline M_{sun}\\ \hline Cnf\\ 481\\ 1981\\ 3156\\ 4524\\ 6052\\ 11893\\ 15376\\ 26227\\ 33227\\ 52116\\ 64771\\ 46129\\ 71199\\ 82487\\ 71199\\ 82487\\ 107559\\ 59590\\ 131375\\ 109018\\ 160043\\ 131575\\ \end{array}$	$\begin{array}{r} 456.3s\\ \hline \\ 7501}\\ \hline \\ 0.1s\\ 0.1s\\ 0.1s\\ 0.1s\\ 0.1s\\ 0.1s\\ 0.2s\\ 0.3s\\ 0.5s\\ 0.3s\\ 0.5s\\ 0.8s\\ 1.4s\\ 2.6s\\ 1.3s\\ 3.2s\\ 2.8s\\ 3.7s\\ 7.8s\\ 2.5s\\ 4.2s\\ 3.4s\\ 4.3s\\ 4.1s\\ \end{array}$	$\begin{array}{c} 1460479\\ \hline\\ & Var\\ 176\\ 607\\ 877\\ 1147\\ 2671\\ 3331\\ 5570\\ 6910\\ 13331\\ 5570\\ 10700\\ 13100\\ 8737\\ 12554\\ 13830\\ 15106\\ 16382\\ 8291\\ 13830\\ 15106\\ 16382\\ 8291\\ 16918\\ 13291\\ 18594\\ 14548\\ \end{array}$	$\begin{array}{c} 3772758\\ \hline M_{sim}\\ \hline Cnf\\ 465\\ 1918\\ 2934\\ 3950\\ 9251\\ 11279\\ 18236\\ 21852\\ 32605\\ 32595\\ 32595\\ 338565\\ 25595\\ 36876\\ 40364\\ 43852\\ 47340\\ 24342\\ 50300\\ 39635\\ 55532\\ 43559\\ \end{array}$	$\begin{array}{c} 237.3\\ \hline T^{sol}\\ 0.1s\\ 0.1s\\ 0.1s\\ 0.2s\\ 0.3s\\ 0.5s\\ 2.2s\\ 1.3s\\ 2.2s\\ 1.3s\\ 2.2s\\ 3.7s\\ 1.7s\\ 2.4s\\ 3.5s\\ 3.7s\\ 2.4s\\ 3.1s\\ 2.3s\end{array}$
$\begin{array}{c} \text{Round} \\ \hline 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \\ 9 \\ 10 \\ 11 \\ 12 \\ 13 \\ 14 \\ 15 \\ 16 \\ 17 \\ 18 \\ 19 \\ 20 \\ 21 \\ 22 \\ 23 \\ \end{array}$	$\begin{array}{c} \log_2 Cor_{opt} \\ \hline 0 \\ -1 \\ -2 \\ -3 \\ -4 \\ -6 \\ -8 \\ -11 \\ -14 \\ -18 \\ -22 \\ -24 \\ -27 \\ -30 \\ -33 \\ -36 \\ -37 \\ -40 \\ -42 \\ -45 \\ -47 \\ -50 \\ -52 \\ \end{array}$	7765375 Lin Var 176 623 1013 1499 2081 4353 6051 11098 15038 25040 32780 24027 37802 44718 52210 60278 33647 74694 62541 92562 76662 76662 92223	$\begin{array}{r} 7187757\\ \hline \textbf{near Pro}\\ \hline M_{sun} & Cnf\\ 481\\ 1981\\ 3156\\ 4524\\ 6052\\ 11893\\ 15376\\ 26227\\ 33227\\ 52116\\ 64771\\ 46129\\ 71199\\ 82487\\ 94607\\ 107559\\ 107559\\ 107559\\ 109018\\ 160043\\ 131575\\ 109018\\ 131575\\ 191527\\ 156244 \end{array}$	$\begin{array}{r} 456.3 \mathrm{s} \\ \hline T^{sol} \\ 0.1 \mathrm{s} \\ 0.2 \mathrm{s} \\ 0.3 \mathrm{s} \\ 0.2 \mathrm{s} \\ 0.3 \mathrm{s} \\ 0.4 \mathrm{s} \\ 1.4 \mathrm{s} \\ 2.6 \mathrm{s} \\ 1.3 \mathrm{s} \\ 3.2 \mathrm{s} \\ 2.8 \mathrm{s} \\ 3.2 \mathrm{s} \\ 2.5 \mathrm{s} \\ 4.2 \mathrm{s} \\ 3.4 \mathrm{s} \\ 4.3 \mathrm{s} \\ 4.3 \mathrm{s} \\ 5.1 \mathrm{s} \\ 5.1 \mathrm{s} \\ 4.5 \mathrm{s} \end{array}$	1460479 Var 176 607 877 1147 1417 2671 3331 5570 6910 10700 8737 12554 13830 15106 16382 8291 16918 13291 18594 14548 20270 15805	$\begin{array}{c} M_{sim} \\ Cnf \\ 465 \\ 1918 \\ 2934 \\ 3950 \\ 4966 \\ 9251 \\ 11279 \\ 18236 \\ 21852 \\ 32605 \\ 38565 \\ 25595 \\ 36876 \\ 40364 \\ 43852 \\ 47340 \\ 24342 \\ 50300 \\ 39635 \\ 55532 \\ 43559 \\ 60764 \\ 47483 \end{array}$	$\begin{array}{c} 237.3\\ \hline T^{sol}\\ 0.1s\\ 0.1s\\ 0.1s\\ 0.1s\\ 0.2s\\ 0.3s\\ 0.2s\\ 0.3s\\ 0.2s\\ 0.3s\\ 0.2s\\ 0.3s\\ 0.2s\\ 0.3s\\ 0.2s\\ 0.3s\\ 0.4s\\ 0.2s\\ 0.3s\\ 0.3s\\ 0.2s\\ 0.3s\\ 0.3s\\ 0.2s\\ 0.3s\\ 0.3s\\ 0.3s\\ 0.2s\\ 0.3s\\ 0.3s\\ 0.3s\\ 0.2s\\ 0.3s\\ 0.3s\\$
$\begin{array}{c} \text{Round} \\ \hline 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \\ 9 \\ 10 \\ 11 \\ 12 \\ 13 \\ 14 \\ 15 \\ 16 \\ 17 \\ 18 \\ 19 \\ 20 \\ 21 \\ 12 \\ 22 \\ 23 \\ 24 \\ \end{array}$	$\begin{array}{c} \log_2 Cor_{opt} \\ \hline 0 \\ -1 \\ -2 \\ -3 \\ -4 \\ -6 \\ -8 \\ -11 \\ -14 \\ -18 \\ -22 \\ -24 \\ -27 \\ -30 \\ -33 \\ -36 \\ -37 \\ -40 \\ -42 \\ -45 \\ -47 \\ -50 \\ -52 \\ -55 \\ -55 \end{array}$	7765375 Lin Var 176 623 1013 1499 2081 4353 6051 11098 15038 25040 32780 24027 37802 44718 52210 60278 33647 74694 62541 92562 76662 112350 92223 134058	$\begin{array}{r} 7187757\\ \hline \textbf{near Pro}\\ \hline M_{sun} & Cnf\\ \hline Cnf\\ 481\\ 1981\\ 3156\\ 4524\\ 6052\\ 11893\\ 15376\\ 26227\\ 33227\\ 52116\\ 64771\\ 146129\\ 71199\\ 82487\\ 94607\\ 10759\\ 94607\\ 1075950\\ 131375\\ 109018\\ 160043\\ 131575\\ 191527\\ 19527\\ \end{array}$	$\begin{array}{r} 456.3 \mathrm{s} \\ \hline \\ 750} \\ \hline \\ 750 \\ \hline \\ 0.1 \mathrm{s} \\ 0.2 \mathrm{s} \\ 0.3 \mathrm{s} \\ 0.3 \mathrm{s} \\ 0.5 \mathrm{s} \\ 0.3 \mathrm{s} \\ 1.4 \mathrm{s} \\ 2.6 \mathrm{s} \\ 1.3 \mathrm{s} \\ 3.2 \mathrm{s} \\ 2.8 \mathrm{s} \\ 3.2 \mathrm{s} \\ 2.8 \mathrm{s} \\ 3.2 \mathrm{s} \\ 2.8 \mathrm{s} \\ 3.2 \mathrm{s} \\ 2.5 \mathrm{s} \\ 4.2 \mathrm{s} \\ 3.4 \mathrm{s} \\ 4.3 \mathrm{s} \\ 4.3 \mathrm{s} \\ 4.1 \mathrm{s} \\ 5.1 \mathrm{s} \\ 4.5 \mathrm{s} \\ 5.5 \mathrm{s} \end{array}$	$\begin{array}{c} 1460479\\ \hline\\ Var\\ 176\\ 607\\ 877\\ 1147\\ 1417\\ 2671\\ 3331\\ 5570\\ 6910\\ 10700\\ 13100\\ 8737\\ 12554\\ 13830\\ 15106\\ 16382\\ 8291\\ 13830\\ 16918\\ 13291\\ 18594\\ 14548\\ 20270\\ 15805\\ 21946\\ \end{array}$	$\begin{array}{c} M_{sim} \\ \hline Cnf \\ 465 \\ 1918 \\ 2934 \\ 3950 \\ 4966 \\ 9251 \\ 11279 \\ 18236 \\ 21852 \\ 32605 \\ 338565 \\ 25595 \\ 36876 \\ 40364 \\ 43852 \\ 47340 \\ 24342 \\ 50300 \\ 39635 \\ 55532 \\ 45595 \\ 60764 \\ 47483 \\ 65996 \end{array}$	$\begin{array}{c} 237.3\\ \hline T^{sol}\\ 0.1s\\ 0.1s\\ 0.1s\\ 0.2s\\ 0.3s\\ 0.2s\\ 0.3s\\ 0.2s\\ 0.3s\\ 0.2s\\ 0.3s\\ 0.2s\\ 0.3s\\ 0.2s\\ 0.3s\\ 0.4s\\ 0.2s\\ 0.3s\\ 0.4s\\ 0.3s\\ 0.3s\\ 0.4s\\ 0.3s\\ 0.3s\\$
$\begin{array}{c} \text{Round} \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \\ 9 \\ 10 \\ 11 \\ 12 \\ 13 \\ 14 \\ 15 \\ 16 \\ 17 \\ 18 \\ 19 \\ 20 \\ 21 \\ 18 \\ 19 \\ 20 \\ 21 \\ 22 \\ 23 \\ 24 \\ 25 \\ \end{array}$	$\begin{array}{c} \log_2 Cor_{opt} \\ 0 \\ -1 \\ -2 \\ -3 \\ -4 \\ -6 \\ -8 \\ -11 \\ -14 \\ -18 \\ -22 \\ -24 \\ -27 \\ -30 \\ -33 \\ -36 \\ -37 \\ -40 \\ -42 \\ -45 \\ -47 \\ -50 \\ -52 \\ -55 \\ -56 \\ \end{array}$	7765375 Lin Var 176 623 1013 1499 2081 4353 6051 11098 15038 25040 32780 24027 37802 44718 52210 60278 33647 74694 62541 92562 74694 62541 92562 74664 62541 92253 1120562 74664 62541 92253 1120562 74664 746966 74697 7469666 746967 74696667 746967 746967 746967	$\begin{array}{r} 7187757\\ \hline \textbf{near Pro}\\ \hline M_{sun} & Cnf\\ \hline 481\\ 1981\\ 3156\\ 4524\\ 6052\\ 11893\\ 15376\\ 26227\\ 33227\\ 52116\\ 64771\\ 46129\\ 71199\\ 82487\\ 94607\\ 107559\\ 59590\\ 131375\\ 109018\\ 160043\\ 131575\\ 1991527\\ 156244\\ 225827\\ 121220\\ \end{array}$	$\begin{array}{r} 456.3\mathrm{s}\\ \mathbf{pperty}\\ \hline T^{sol}\\ 0.1\mathrm{s}\\ 0.1\mathrm{s}\\ 0.1\mathrm{s}\\ 0.1\mathrm{s}\\ 0.1\mathrm{s}\\ 0.1\mathrm{s}\\ 0.2\mathrm{s}\\ 0.3\mathrm{s}\\ 0.3\mathrm{s}\\ 0.5\mathrm{s}\\ 1.4\mathrm{s}\\ 2.6\mathrm{s}\\ 1.3\mathrm{s}\\ 1.3\mathrm{s}\\ 3.2\mathrm{s}\\ 2.8\mathrm{s}\\ 3.7\mathrm{s}\\ 7.8\mathrm{s}\\ 2.8\mathrm{s}\\ 3.7\mathrm{s}\\ 7.8\mathrm{s}\\ 2.4\mathrm{s}\\ 4.2\mathrm{s}\\ 3.4\mathrm{s}\\ 4.2\mathrm{s}\\ 3.4\mathrm{s}\\ 4.1\mathrm{s}\\ 5.1\mathrm{s}\\ 5.5\mathrm{s}\\ 2.8\mathrm{s}\\ 2.8\mathrm{s}\\ 3.4\mathrm{s}\\ 4.3\mathrm{s}\\ 4.3\mathrm{s}\\ 4.3\mathrm{s}\\ 4.3\mathrm{s}\\ 4.3\mathrm{s}\\ 4.3\mathrm{s}\\ 5.5\mathrm{s}\\ 2.8\mathrm{s}\\ 3.8\mathrm{s}\\ 3.8\mathrm{s}\\$	$\begin{array}{c} 1460479\\ \hline\\ Var\\ 176\\ 607\\ 877\\ 1147\\ 1417\\ 2671\\ 3331\\ 5570\\ 6910\\ 10700\\ 13100\\ 8737\\ 12554\\ 13830\\ 15106\\ 16382\\ 8291\\ 15106\\ 16382\\ 8291\\ 18594\\ 14548\\ 20270\\ 15805\\ 21946\\ 10977\\ \end{array}$	$\begin{array}{c} M_{sim} \\ \hline Cnf \\ 465 \\ 1918 \\ 2934 \\ 3950 \\ 4966 \\ 9251 \\ 11279 \\ 18236 \\ 21852 \\ 32605 \\ 33565 \\ 21852 \\ 32605 \\ 33565 \\ 25595 \\ 36876 \\ 40364 \\ 43852 \\ 47340 \\ 24342 \\ 50300 \\ 39635 \\ 55532 \\ 43559 \\ 60764 \\ 47483 \\ 5596 \\ 33478 \\ \end{array}$	$\begin{array}{c} 237.3 \\ \hline \\ T^{sol} \\ 0.1s \\ 0.1s \\ 0.1s \\ 0.1s \\ 0.2s \\ 0.2s \\ 0.3s \\ 0.2s \\ 0.3s \\ 0.2s \\ 0.3s \\ 0.2s \\ 0.3s \\ 0.2s \\ 0$
$\begin{array}{c} \text{Round} \\ \hline 1 \\ 2 \\ \hline 3 \\ 4 \\ 5 \\ \hline 6 \\ 7 \\ 7 \\ 8 \\ 9 \\ 10 \\ 11 \\ 12 \\ 13 \\ 14 \\ 15 \\ 16 \\ 17 \\ 18 \\ 19 \\ 20 \\ 21 \\ 22 \\ 23 \\ 24 \\ 25 \\ 26 \\ \end{array}$	$\begin{array}{c} \log_2 Cor_{opt} \\ \hline 0 \\ -1 \\ -2 \\ -3 \\ -4 \\ -6 \\ -8 \\ -11 \\ -14 \\ -18 \\ -22 \\ -24 \\ -27 \\ -30 \\ -33 \\ -36 \\ -37 \\ -40 \\ -45 \\ -47 \\ -50 \\ -52 \\ -55 \\ -56 \\ -59 \\ \end{array}$	7765375 <i>Var</i> 176 623 1013 1499 2081 4353 6051 11098 15038 25040 32780 24027 37802 3647 74694 62541 32760 2223 134055 72217 155194	$\begin{array}{r} 7187757\\ \hline \textbf{Pear Pro}\\ \hline M_{sun} & Cnf\\ \hline 481\\ 1981\\ 3156\\ 4524\\ 4524\\ 4524\\ 4524\\ 5022\\ 11893\\ 15376\\ 26227\\ 33227\\ 52116\\ 64771\\ 46129\\ 71199\\ 82487\\ 71199\\ 82487\\ 107559\\ 59590\\ 131375\\ 199597\\ 131375\\ 109018\\ 160043\\ 131575\\ 191527\\ 156244\\ 225827\\ 121220\\ 259627\\ \end{array}$	$\begin{array}{r} 456.3s\\ \hline \\ 7501}\\ \hline \\ 7501\\ \hline \\ 0.1s\\ \hline \\ 0.2s\\ \hline \\ 0.3s\\ \hline \\ 0.2s\\ \hline \\ 0.3s\\ \hline \\ 0.3s\\ \hline \\ 0.4s\\ \hline \\ 0.2s\\ \hline \\ 0.3s\\ \hline \\ 0.4s\\ \hline \\ 0.2s\\ \hline \\ 0.4s\\ \hline \\ 0.2s\\ \hline 0.2s$	1460479           Var           176           607           877           1417           2671           3331           5570           6910           10700           13100           8737           12554           13830           15106           16382           8291           16918           138594           14548           20270           15805           21946           10977           22098	$\begin{array}{c} 3772758\\ \hline M_{sim} \\ \hline Cnf\\ 465\\ 1918\\ 2934\\ 3950\\ 9251\\ 11279\\ 18236\\ 21852\\ 21852\\ 32605\\ 32505\\ 32505\\ 32505\\ 32595\\ 36876\\ 40364\\ 43852\\ 47340\\ 24342\\ 50300\\ 39635\\ 55532\\ 43559\\ 60764\\ 47483\\ 65996\\ 60764\\ 47483\\ 65986\\ 8188\\ \hline \end{array}$	$\begin{array}{c} 237.3\\ \hline T^{sol}\\ 0.1s\\ 0.1s\\ 0.1s\\ 0.2s\\ 0.3s\\ 0.4s\\ 0.2s\\ 0.3s\\ 0.5s\\ 0.8s\\ 0.4s\\ 0.4s\\$
$\begin{array}{c} \text{Round} \\ \hline 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \\ 9 \\ 10 \\ 11 \\ 12 \\ 13 \\ 14 \\ 15 \\ 16 \\ 17 \\ 18 \\ 19 \\ 20 \\ 21 \\ 12 \\ 23 \\ 24 \\ 25 \\ 26 \\ 27 \\ \end{array}$	$\begin{array}{c} \log_2 Cor_{opt} \\ \hline 0 \\ -1 \\ -2 \\ -3 \\ -6 \\ -8 \\ -11 \\ -14 \\ -14 \\ -12 \\ -27 \\ -30 \\ -37 \\ -40 \\ -42 \\ -27 \\ -30 \\ -33 \\ -36 \\ -37 \\ -40 \\ -42 \\ -47 \\ -50 \\ -52 \\ -55 \\ -56 \\ -59 \\ -62 \\ \end{array}$	7765375 Var 176 623 1013 1499 2081 4353 6051 11098 4353 6051 11098 25040 32780 24027 37802 24027 3662 74694 62541 92562 112350 92223 134058 72217 155194 168926	$\begin{array}{r} 7187757\\ \hline \textbf{Pear Proc}\\ \hline M_{sun}\\ \hline Cnf\\ 481\\ 1981\\ 3156\\ 4524\\ 6052\\ 11893\\ 15376\\ 26227\\ 33227\\ 52116\\ 64771\\ 46129\\ 71199\\ 82487\\ 94607\\ 107559\\ 59590\\ 131375\\ 109018\\ 160043\\ 131575\\ 191527\\ 156244\\ 225827\\ 121220\\ 259627\\ 280835\\ \end{array}$	$\begin{array}{r} 456.3 \mathrm{s} \\ \hline \\ 7501} \\ \hline \\ 0.1 \mathrm{s} \\ 0.2 \mathrm{s} \\ 0.3 \mathrm{s} \\ 0.3 \mathrm{s} \\ 0.5 \mathrm{s} \\ 0.3 \mathrm{s} \\ 0.4 \mathrm{s} \\ 1.4 \mathrm{s} \\ 2.6 \mathrm{s} \\ 1.3 \mathrm{s} \\ 3.2 \mathrm{s} \\ 2.8 \mathrm{s} \\ 3.2 \mathrm{s} \\ 2.5 \mathrm{s} \\ 4.2 \mathrm{s} \\ 3.4 \mathrm{s} \\ 4.1 \mathrm{s} \\ 5.1 \mathrm{s} \\ 4.5 \mathrm{s} \\ 5.1 \mathrm{s} \\ 4.5 \mathrm{s} \\ 5.8 \mathrm{s} \\ 2.8 \mathrm{s} \\ 6.7 \mathrm{s} \\ 9.3 \mathrm{s} \end{array}$	Var           176           607           877           1147           1417           3331           5570           6910           10700           13100           8737           12554           13830           15106           16382           8291           16918           13291           18594           14548           20270           15805           21946           10977           22098           23822	$\begin{array}{c} 3772758\\ \hline M_{sim} \\ Cnf\\ 465\\ 1918\\ 2934\\ 3950\\ 4966\\ 9251\\ 11279\\ 18236\\ 21852\\ 32605\\ 38565\\ 25595\\ 38565\\ 25595\\ 38565\\ 25595\\ 38576\\ 40364\\ 43852\\ 43852\\ 55532\\ 43359\\ 60764\\ 47483\\ 65996\\ 33478\\ 68188\\ 72572\\ \end{array}$	$\begin{array}{c} 237.3\\ \hline T^{sol}\\ 0.1s\\ 0.1s\\ 0.1s\\ 0.1s\\ 0.2s\\ 0.3s\\ 0.2s\\ 0.2s\\$
$\begin{array}{c} \text{Round} \\ \hline 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \\ 9 \\ 10 \\ 11 \\ 12 \\ 13 \\ 14 \\ 15 \\ 16 \\ 17 \\ 18 \\ 19 \\ 20 \\ 21 \\ 22 \\ 23 \\ 24 \\ 25 \\ 26 \\ 27 \\ 28 \\ \end{array}$	$\begin{array}{c} \log_2 Cor_{opt} \\ 0 \\ -1 \\ -2 \\ -3 \\ -4 \\ -6 \\ -8 \\ -11 \\ -14 \\ -18 \\ -22 \\ -24 \\ -27 \\ -30 \\ -33 \\ -36 \\ -37 \\ -40 \\ -42 \\ -45 \\ -47 \\ -50 \\ -52 \\ -55 \\ -56 \\ -59 \\ -62 \\ -65 \\ -65 \\ -65 \\ -65 \\ -65 \\ -65 \\ -65 \\ -10$	7765375 Var 176 623 1013 1499 2081 4353 6051 11098 15038 25040 32780 24027 37802 44718 52210 60278 33647 74694 62541 92562 72627 76662 112350 92223 134058 72217 155194 168926 183234	$\begin{array}{r} 7187757\\ \hline \textbf{Pear Pro}\\ \hline M_{sun} & Cnf\\ 481\\ 1981\\ 3156\\ 4524\\ 6052\\ 11893\\ 15376\\ 26227\\ 33227\\ 52116\\ 64771\\ 46129\\ 71199\\ 82487\\ 946075\\ 107559\\ 59590\\ 131375\\ 107559\\ 59590\\ 131375\\ 109018\\ 160043\\ 131575\\ 191527\\ 156244\\ 225827\\ 121220\\ 259627\\ 121220\\ 259627\\ 302875\\ 302875\\ \end{array}$	$\begin{array}{r} 456.3 \mathrm{s} \\ \hline \\ 7501} \\ \hline \\ 0.1 \mathrm{s} \\ 0.2 \mathrm{s} \\ 0.3 \mathrm{s} \\ 0.3 \mathrm{s} \\ 0.5 \mathrm{s} \\ 0.3 \mathrm{s} \\ 0.4 \mathrm{s} \\ 1.4 \mathrm{s} \\ 2.6 \mathrm{s} \\ 1.3 \mathrm{s} \\ 3.2 \mathrm{s} \\ 2.8 \mathrm{s} \\ 3.2 \mathrm{s} \\ 2.8 \mathrm{s} \\ 3.2 \mathrm{s} \\ 2.5 \mathrm{s} \\ 4.2 \mathrm{s} \\ 3.4 \mathrm{s} \\ 4.2 \mathrm{s} \\ 3.4 \mathrm{s} \\ 4.1 \mathrm{s} \\ 5.1 \mathrm{s} \\ 4.5 \mathrm{s} \\ 5.5 \mathrm{s} \\ 2.8 \mathrm{s} \\ 6.7 \mathrm{s} \\ 9.3 \mathrm{s} \\ 16.1 \mathrm{s} \end{array}$	1460479           Var           176           607           877           1147           1417           3331           5570           6910           10700           13100           8737           12554           13830           15106           16382           8291           16918           13291           18594           14548           20270           15805           21946           10977           22098           23822           25546	$\begin{array}{c} M_{sim} \\ Cnf \\ 465 \\ 1918 \\ 2934 \\ 3950 \\ 4966 \\ 9251 \\ 11279 \\ 18236 \\ 21852 \\ 32605 \\ 25595 \\ 38565 \\ 25595 \\ 38565 \\ 25595 \\ 38676 \\ 40364 \\ 43852 \\ 47340 \\ 24342 \\ 50300 \\ 39635 \\ 55532 \\ 43559 \\ 60764 \\ 47483 \\ 65996 \\ 33478 \\ 68188 \\ 68188 \\ 72572 \\ 76956 \end{array}$	$\begin{array}{c} 237.3\\ \hline T^{sol}\\ 0.1s\\ 0.1s\\ 0.1s\\ 0.1s\\ 0.2s\\ 0.3s\\ 0.2s\\ 0.2s\\$
$\begin{array}{c} \text{Round} \\ \hline 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \\ 9 \\ 10 \\ 11 \\ 12 \\ 13 \\ 14 \\ 15 \\ 16 \\ 17 \\ 18 \\ 19 \\ 20 \\ 21 \\ 19 \\ 20 \\ 21 \\ 22 \\ 23 \\ 24 \\ 25 \\ 26 \\ 27 \\ 28 \\ 29 \\ \end{array}$	$\begin{array}{c} \log_2 Cor_{opt} \\ \hline 0 \\ -1 \\ -2 \\ -3 \\ -4 \\ -6 \\ -8 \\ -11 \\ -14 \\ -18 \\ -22 \\ -24 \\ -27 \\ -30 \\ -33 \\ -36 \\ -37 \\ -40 \\ -42 \\ -45 \\ -47 \\ -50 \\ -52 \\ -55 \\ -56 \\ -59 \\ -62 \\ -65 \\ -66 \\ -66 \\ -66 \\ -66 \\ -66 \\ -66 \\ -1 \\ -1$	7765375 Var 176 623 1013 1499 2081 4353 6051 11098 15038 25040 32780 24027 37802 44718 52210 60278 33647 74694 62541 92562 76662 112350 92223 134058 72217 155194 1689266	$\begin{array}{r} 7187757\\ \hline \textbf{near Pro}\\ \hline M_{sun} & \hline Cnf \\ 481 \\ 1981 \\ 3156 \\ 4524 \\ 6052 \\ 4524 \\ 6052 \\ 1893 \\ 15376 \\ 26227 \\ 33227 \\ 52116 \\ 26227 \\ 33227 \\ 52116 \\ 64771 \\ 46129 \\ 71199 \\ 82487 \\ 94607 \\ 107559 \\ 94607 \\ 107559 \\ 59590 \\ 131375 \\ 109018 \\ 160043 \\ 131575 \\ 109018 \\ 160043 \\ 131575 \\ 156244 \\ 225827 \\ 121220 \\ 259627 \\ 280835 \\ 161024 \\ \end{array}$	$\begin{array}{r} 456.3 \mathrm{s} \\ \hline \\ 7501} \\ \hline \\ 0.1 \mathrm{s} \\ 0.2 \mathrm{s} \\ 0.3 \mathrm{s} \\ 0.3 \mathrm{s} \\ 0.5 \mathrm{s} \\ 0.3 \mathrm{s} \\ 0.4 \mathrm{s} \\ 1.4 \mathrm{s} \\ 2.6 \mathrm{s} \\ 3.2 \mathrm{s} \\ 2.8 \mathrm{s} \\ 3.4 \mathrm{s} \\ 4.3 \mathrm{s} \\ 4.3 \mathrm{s} \\ 4.3 \mathrm{s} \\ 5.1 \mathrm{s} \\ 5.5 \mathrm{s} \\ 2.8 \mathrm{s} \\ 6.7 \mathrm{s} \\ 9.3 \mathrm{s} \\ 16.1 \mathrm{s} \\ 4.3 \mathrm{s} \\ 4.3 \mathrm{s} \\ 4.3 \mathrm{s} \\ 4.3 \mathrm{s} \\ 16.1 \mathrm{s} \\ 4.3 \mathrm{s} \\ 4.3 \mathrm{s} \\ 1.3 $	1460479 Var 176 607 877 1147 1417 2671 3331 5570 6910 10700 13100 8737 12554 13830 15106 16382 13291 16918 13291 16918 13291 14548 20270 15805 21946 10977 22098 23822 25546 12713	$\begin{array}{c} 3772758\\ \hline \\ M_{sim}\\ \hline \\ Cnf\\ 465\\ 1918\\ 2934\\ 3950\\ 4966\\ 9251\\ 11279\\ 18236\\ 21852\\ 32605\\ 338565\\ 25595\\ 36876\\ 40364\\ 43852\\ 47340\\ 24342\\ 50300\\ 39635\\ 55532\\ 43559\\ 60764\\ 47483\\ 65996\\ 33478\\ 68188\\ 72572\\ 76956\\ 38830\\ \end{array}$	$\begin{array}{c} 237.3\\ \hline T^{sol}\\ 0.1s\\ 0.1s\\ 0.1s\\ 0.2s\\ 0.3s\\ 0.4s\\ 0.3s\\ 0.5s\\ 0.4s\\ 0.5s\\ 0.4s\\ 0.5s\\ 0.4s\\ 0.5s\\ 0.4s\\ 0.5s\\ 0.4s\\ 0.5s\\ 0.4s\\ 0.5s\\ 0.4s\\ 0.4s\\$
$\begin{array}{c} \text{Round} \\ \hline 1 \\ 2 \\ \hline 3 \\ 4 \\ 5 \\ \hline 6 \\ 7 \\ \hline 8 \\ 9 \\ 10 \\ 11 \\ 12 \\ 13 \\ 14 \\ 15 \\ 16 \\ 17 \\ 18 \\ 19 \\ 20 \\ 21 \\ 13 \\ 14 \\ 15 \\ 26 \\ 27 \\ 23 \\ 24 \\ 25 \\ 26 \\ 27 \\ 28 \\ 29 \\ 30 \\ \end{array}$	$\begin{array}{c} \log_2 Cor_{opt} \\ 0 \\ -1 \\ -2 \\ -3 \\ -4 \\ -6 \\ -8 \\ -11 \\ -14 \\ -18 \\ -22 \\ -24 \\ -27 \\ -30 \\ -33 \\ -36 \\ -37 \\ -40 \\ -42 \\ -45 \\ -47 \\ -50 \\ -55 \\ -56 \\ -59 \\ -66 \\ -69 \\ -69 \\ \end{array}$	7765375 Lin Var 176 623 1013 1499 2081 4353 6051 11098 15038 25040 32780 24027 37802 44718 52210 60278 33647 74694 62541 92562 76662 112350 60278 134058 72217 155194 168926 183234 97669 207826	$\begin{array}{r} 7187757\\ \hline \textbf{near Pro}\\ \hline M_{sun} & \hline Cnf\\ \hline Asian & \hline Cnf\\ \hline asian & \hline Cnf\\ \hline asian & \hline $	$\begin{array}{r} 456.3 \mathrm{s} \\ \hline 456.3 \mathrm{s} \\ \hline perty \\ \hline \\ 0.1 \mathrm{s} \\ 0.2 \mathrm{s} \\ 0.3 \mathrm{s} \\ 0.3 \mathrm{s} \\ 0.3 \mathrm{s} \\ 1.4 \mathrm{s} \\ 2.6 \mathrm{s} \\ 1.3 \mathrm{s} \\ 3.2 \mathrm{s} \\ 2.8 \mathrm{s} \\ 3.7 \mathrm{s} \\ 7.8 \mathrm{s} \\ 2.8 \mathrm{s} \\ 3.7 \mathrm{s} \\ 7.8 \mathrm{s} \\ 2.8 \mathrm{s} \\ 3.7 \mathrm{s} \\ 7.8 \mathrm{s} \\ 2.8 \mathrm{s} \\ 3.7 \mathrm{s} \\ 7.8 \mathrm{s} \\ 2.5 \mathrm{s} \\ 5.1 \mathrm{s} \\ 5.1 \mathrm{s} \\ 5.5 \mathrm{s} \\ 2.8 \mathrm{s} \\ 6.7 \mathrm{s} \\ 9.3 \mathrm{s} \\ 16.1 \mathrm{s} \\ 4.3 \mathrm{s} \\ 6.3 \mathrm{s} \\ 6.3 \mathrm{s} \\ \end{array}$	1460479 Var 176 607 877 1147 2671 3331 5570 6910 10700 13100 13100 13100 13100 13100 16382 8291 13894 14548 20270 15805 21946 10977 22098 23822 25546	$\begin{array}{c} 3772758\\ \hline \\ M_{sim}\\ \hline \\ Cnf\\ 465\\ 1918\\ 2934\\ 3950\\ 9251\\ 11279\\ 18236\\ 21852\\ 32605$	$\begin{array}{c} 237.3\\ \hline T^{sol}\\ 0.1s\\ 0.1s\\ 0.1s\\ 0.1s\\ 0.2s\\ 0.2s\\$
$\begin{array}{c} \text{Round} \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \\ 9 \\ 10 \\ 11 \\ 12 \\ 13 \\ 14 \\ 15 \\ 16 \\ 17 \\ 18 \\ 19 \\ 20 \\ 21 \\ 22 \\ 23 \\ 24 \\ 25 \\ 26 \\ 27 \\ 28 \\ 29 \\ 29 \\ 30 \\ 31 \\ \end{array}$	$\begin{array}{c} \log_2 Cor_{opt} \\ 0 \\ -1 \\ -2 \\ -3 \\ -4 \\ -6 \\ -8 \\ -11 \\ -14 \\ -18 \\ -22 \\ -24 \\ -27 \\ -30 \\ -33 \\ -36 \\ -37 \\ -40 \\ -42 \\ -45 \\ -47 \\ -50 \\ -52 \\ -55 \\ -56 \\ -59 \\ -62 \\ -65 \\ -66 \\ -69 \\ -72 \\ \end{array}$	7765375 <i>Var</i> 176 623 1013 1499 2081 4353 6051 11098 15038 25040 32780 24027 37802 24027 3280 22504 12350 2023 134058 72210 2023 134058 72217 155194 168926 20789 20789 20780 2023 134058 72217 155194 168926 20789 20789 20780 2023 134058 72217 155194 168926 20789 20789 20780 20780 2023 134058 72217 155194 168926 20789 207866 20789 20780 20780 20780 20780 20780 20780 20780 20780 20780 20780 20780 20780 20780 20780 207826 20780 20780 207826 207826 20780 207826 207827 207826 207826 207826 207826 207826 207826 207827 207826 207826 207826 207827 207826 207826 207827 207826 207827 207826 207827 207826 207827 207826 207827 207826 207827 207826 207827 207826 207827 207826 207826 207827 207826 207827 207826 207827 207826 207827 207826 207827 207826 207827 207826 207827 207826 207827 207826 207827 207826 207827 20787 20787 20787 20787 20787 20787 20787 207877 207877 2078777 2078777 207877777777	$\begin{array}{r} 7187757\\ \hline \textbf{Pear Pro}\\ \hline M_{sun} & Cnf\\ \hline 481\\ 1981\\ 3156\\ 4524\\ 6052\\ 11893\\ 15376\\ 26227\\ 33227\\ 52116\\ 64771\\ 46129\\ 71199\\ 82487\\ 94607\\ 107559\\ 59590\\ 131375\\ 109018\\ 160043\\ 131575\\ 191527\\ 156244\\ 225827\\ 121220\\ 259627\\ 280835\\ 302875\\ 161024\\ 341795\\ 366075\\ \end{array}$	$\begin{array}{r} 456.3s\\ \hline \\ 7501}\\ \hline \\ 7501\\ \hline \\ 0.1s\\ \hline \\ 0.2s\\ \hline \\ 0.3s\\ \hline \\ 0.3s\\ \hline \\ 0.4s\\ \hline \\ 0.5s\\ \hline \\ 0.8s\\ \hline \\ 0.4s\\ \hline \\ 0.2s\\ \hline \\ 0.3s\\ \hline \\ 0.5s\\ \hline \\ 0.4s\\ \hline \\ 0.2s\\ \hline \\ 0.3s\\ \hline \\ 0.5s\\ \hline \\ 0.3s\\ \hline 0.3s\\ \hline \\ 0.3s\\ \hline 0.$	1460479 Var 176 607 877 1417 2671 3331 5570 6910 13100 8737 12554 13830 15106 16382 8291 16918 13291 18594 14548 20270 18859 18594 14548 20270 15805 21946 12713 25442 27294	$\begin{array}{c} 3772758\\ \hline M_{sim}\\ \hline Cnf\\ 465\\ 1918\\ 2934\\ 3950\\ 4966\\ 9251\\ 11279\\ 18236\\ 21852\\ 32605\\ 32555\\ 32595\\ 33676\\ 40364\\ 43852\\ 47340\\ 24342\\ 50300\\ 39635\\ 55532\\ 43559\\ 60764\\ 47483\\ 65996\\ 33478\\ 68188\\ 72572\\ 76956\\ 38830\\ 78636\\ 83276\\ \end{array}$	$\begin{array}{c} 237.3;\\ \hline T^{sol}\\ 0.1s\\ 0.1s\\ 0.1s\\ 0.2s\\ 0.3s\\ 0.5s\\ 0.3s\\ 0.5s\\ 0.3s\\ 0.5s\\ 0.3s\\ 0.5s\\ 0.8s\\ 0.3s\\ 0.4s\\ 0.3s\\ 0.4s\\ 0.3s\\ 0.4s\\ 0.4s$
$\begin{array}{c} \text{Round} \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \\ 9 \\ 10 \\ 11 \\ 12 \\ 13 \\ 14 \\ 15 \\ 16 \\ 17 \\ 18 \\ 19 \\ 20 \\ 21 \\ 18 \\ 19 \\ 20 \\ 21 \\ 22 \\ 23 \\ 24 \\ 25 \\ 26 \\ 27 \\ 28 \\ 29 \\ 30 \\ \end{array}$	$\begin{array}{c} \log_2 Cor_{opt} \\ 0 \\ -1 \\ -2 \\ -3 \\ -4 \\ -6 \\ -8 \\ -11 \\ -14 \\ -18 \\ -22 \\ -24 \\ -27 \\ -30 \\ -33 \\ -36 \\ -37 \\ -40 \\ -42 \\ -45 \\ -47 \\ -50 \\ -55 \\ -56 \\ -59 \\ -66 \\ -69 \\ -69 \\ \end{array}$	7765375 Lin Var 176 623 1013 1499 2081 4353 6051 11098 15038 25040 32780 24027 37802 44718 52210 60278 33647 74694 62541 92562 76662 112350 60278 134058 72217 155194 168926 183234 97669 207826	$\begin{array}{r} 7187757\\ \hline \textbf{near Pro}\\ \hline M_{sun} & \hline Cnf\\ \hline Asian & \hline Cnf\\ \hline asian & \hline Cnf\\ \hline asian & \hline $	$\begin{array}{r} 456.3 \mathrm{s} \\ \hline 456.3 \mathrm{s} \\ \hline perty \\ \hline \\ 0.1 \mathrm{s} \\ 0.2 \mathrm{s} \\ 0.3 \mathrm{s} \\ 0.3 \mathrm{s} \\ 0.3 \mathrm{s} \\ 1.4 \mathrm{s} \\ 2.6 \mathrm{s} \\ 1.3 \mathrm{s} \\ 3.2 \mathrm{s} \\ 2.8 \mathrm{s} \\ 3.7 \mathrm{s} \\ 7.8 \mathrm{s} \\ 2.8 \mathrm{s} \\ 3.7 \mathrm{s} \\ 7.8 \mathrm{s} \\ 2.8 \mathrm{s} \\ 3.7 \mathrm{s} \\ 7.8 \mathrm{s} \\ 2.8 \mathrm{s} \\ 3.7 \mathrm{s} \\ 7.8 \mathrm{s} \\ 2.5 \mathrm{s} \\ 5.1 \mathrm{s} \\ 5.1 \mathrm{s} \\ 5.5 \mathrm{s} \\ 2.8 \mathrm{s} \\ 6.7 \mathrm{s} \\ 9.3 \mathrm{s} \\ 16.1 \mathrm{s} \\ 4.3 \mathrm{s} \\ 6.3 \mathrm{s} \\ 6.3 \mathrm{s} \\ \end{array}$	1460479 Var 176 607 877 1147 2671 3331 5570 6910 10700 13100 13100 13100 13100 13100 16382 8291 13894 14548 20270 15805 21946 10977 22098 23822 25546	$\begin{array}{c} 3772758\\ \hline \\ M_{sim}\\ \hline \\ Cnf\\ 465\\ 1918\\ 2934\\ 3950\\ 9251\\ 11279\\ 18236\\ 21852\\ 32605$	$\begin{array}{c} 0.1s\\ 0.1s\\ 0.1s\\ 0.1s\\ 0.2s\\ 0.2s\\$

		Differe	ential Pi	oper	ty			
Round	lam D		$M_{sun}$		$M_{sim}$			
Round	$\log_2 P_{opt}$	Var	Cnf	$T^{sol}$	Var	Cnf	$T^{sol}$	
1	0	184	761	0.6s	184	737	0.4s	
2	-2	1053	4814	1.0s	1051	4691	1.1s	
3	-4	1911	8104	1.1s	1615	7295	1.2s	
4	-6	3057	12091	1.1s	2179	9899	1.3s	
5	-8	4491	16726	1.1s	2743	12503	1.1s	
6	-12	11070	38106	2.0s	6210	26565	1.9s	
7	-16	16210	51561	2.1s	8410	33405	2.5s	
8	-22	32571	96545	3.6s	16149	58919	3.3s	
9	-28	45633	127436	4.1s	21609	73227	4.0s	
10	-38	100661	265893	10.9s	47575	147587	8.6s	
11	-46	111870	283105	15.2s	51312	149829	11.3s	
12	-51	92541	229174	11.0s	38657	111682	7.9s	
13	-58	148588	362181	22.8s	56940	163576	20.9s	
14	-64	155253	372989	30.1s	55307	157479	15.8s	
15	-68	127790	304341	14.3s	40920	117745	9.4s	
16	-74	204239	482693	39.5s	59647	172963	28.9s	
17	-77	131330	308567	15.0s	34410	101436	7.6s	
18	-83	256928	600482	32.3s	61348	183183	17.8s	
19	-88	247479	574738	35.2s	55775	166306	27.4s	
20	-94	322371	744437	60.4s	68985	205247	21.8s	
21	-97	202482	465815	14.0s	39554	119500	7.8s	
22	-103	387828	889106	26.3s	70014	214123	12.6s	
23	-107	303395	692916	10.5s	51545	158445	5.6s	
24	-113	463358	1054586	24.9s	74690	230279	13.5s	
25	-116	286598	650531	11.1s	42718	133612	4.6s	
26	-122	541247	1225463	17.2s	75383	238483	7.9s	
27	-126	417660	943011	18.5s	55500	176085	5.8s	
28	-132	629881	1418495	28.5s	60760	189025	6.6s	
29	-136	483370	1085931	21.8s	59080	188105	9.2s	
30	-142	725235	1625639	54.7s	64580	201525	12.6s	
31	-146	553880	1238931	28.3s	62660	200125	12.0s	
32	-152	827309	1846895	41.3s	68400	214025	15.1s	
33	-155	501770	1118447	22.8s	51418	166572	7.6s	
34	-161	930398	2070860	39.1s	56350	178372	6.8s	
35	-166	848643	1885174	68.0s	70310	225145	23.7s	
36	-172	1051617	2331743	74.8s	76510	239965	21.4s	
Total		11169901	25428287	805.3s	1610498	4977660	366.8s	
		Line	ar Prop	perty				
D 1	lan Can		$M_{sun}$			$M_{sim}$		
Round	$\log_2 Cor_{opt}$	Var	Cnf	Tsol	Var	Cnf	$T^{sol}$	

 Table 9. Experimental results of TWINE

Cnf 777 3165 Cnf 761 3102 Т Va 1 0.6s 0.7s 0.7s 0.8s 176 176 607 
 761
 0.3s

 3102
 0.7s

 4710
 0.7s

 6318
 0.8s
 941 1339 4932 6892 877 -2 -3 1801 3633 9012 17221 0.7s 1.2s  $1417 \\ 2671$ 7926 0.7s 14579 1.1s -4 -8 4875 -11 8666 11438 18640 23980 17403 -14 -18 10-22 -24 -27 11 12 13 14 27194 31950 -30 15 16 -32 -35 2745941594-36 -39 17 18 19 20 21 22 23 24 -41 -44 -45 -48 -50 -53 25 26 -54 -57 
 101034
 203719
 5.0s
 20300
 50492
 2.0s

 84258
 228145
 5.0s
 16384
 75455
 3.2s

 120974
 325311
 8.0s
 17851
 79979
 3.5s
 -59 -62 27 28 29 30 -63 -66 31 -68 32 33 -71 -72 -75 34 35 36 -80

Total

		Dif	ferentia	l Propert	у		
Round	$\log_2 P_{opt}$		$M_{sun}$			M <sub>sim</sub>	
nound	log <sub>2</sub> I opt	Var	Cnf	$T^{sol}$	Var	Cnf	$T^{sol}$
1	0	79	294	0.5s	79	279	0.1s
2	-1	281	1229	1.9s	281	1170	0.1s
3	-3	783	3154	2.1s	691	2837	0.2s
4	-5	1368	5002	1.7s	1000	3995	0.2s
5	-9	3925	12826	2.6s	2535	9285	0.6s
6	-13	6465	19176	3.4s	3665	12425	1.8s
7	-18	11838	32782	9.3s	6050	19264	6.7s
8	-24	20349	53299	55.2s	9653	28875	41.9s
9	-30	28511	71702	417.5s	12565	35903	299.9s
10	-34	26350	64751	484.3s	10340	29245	248.0s
11	-38	32265	78226	805.1s	11095	31635	764.8s
12	-42	38780	92976	1211.5s	11850	34025	852.1s
13	-45	36328	86427	680.1s	9704	28376	292.8s
14	-49	52565	124216	1071.1s	12495	37085	698.4s
15	-54	73638	172510	2213.9s	16646	48856	878.3s
16	-58	70840	164726	1368.0s	15160	44165	690.1s
17	-63	97188	224542	4808.5s	19844	57352	3472.7s
18	-69	130424	299069	32243.4s	26796	75411	20902.7
19	-74	127386	290218	101072.8s	25982	71704	58801.5
20	-77	94186	213859	20315.6s	17642	49148	15312.9
21	-81	129125	292506	35272.9s	21855	61925	36305.5
22	-85	141865	320456	31015.1s	22385	63865	21320.6
Total		1124539	2623946	233056.3s	258313	746825	160891.4
		1	Linear P	roperty			
Round	log. Cor		Linear P $M_{sun}$	roperty		M <sub>sim</sub>	
	$\log_2 Cor_{opt}$	Var	M <sub>sun</sub> Cnf	$T^{sol}$	Var	Cnf	$T^{sol}$
1	0	Var 111	$\begin{array}{c} M_{sun} \\ \hline Cnf \\ 455 \end{array}$	$\frac{T^{sol}}{0.1s}$	111	Cnf 440	$\frac{T^{sol}}{0.1s}$
1 2	0	Var 111 190	$     M_{sun}     Cnf     455     924 $	$     T^{sol}     0.1s     0.1s $	111 190	Cnf 440 879	$     T^{sol} \\     0.1s \\     0.1s $
1 2 3	0 0 -1	Var 111 190 582	$M_{sun}$ Cnf 455 924 2855	$     T^{sol}     0.1s     0.1s     0.1s     0.1s   $	111 190 582	$\begin{array}{c} Cnf \\ 440 \\ 879 \\ 2722 \end{array}$	$     \begin{array}{r} T^{sol} \\         0.1s \\         0.s \\ $
$ \begin{array}{c} 1\\ 2\\ 3\\ 4 \end{array} $	0 0 -1 -3	Var 111 190 582 1398	$     \begin{array}{r} M_{sun} \\ Cnf \\ 455 \\ 924 \\ 2855 \\ 6232 \end{array} $	$     T^{sol} \\     0.1s \\     0.1s \\     0.1s \\     0.2s \\     0.2s $	$     \begin{array}{r}       111 \\       190 \\       582 \\       1306     \end{array} $		$     \begin{array}{r} T^{sol} \\         0.1s \\         0.1s \\         0.1s \\         0.2s \\         \end{array} $
	0 0 -1 -3 -5	Var 111 190 582 1398 2169	$\begin{array}{r} M_{sun} \\ Cnf \\ 455 \\ 924 \\ 2855 \\ 6232 \\ 8788 \end{array}$		111 190 582 1306 1801	$\begin{array}{r} Cnf \\ 440 \\ 879 \\ 2722 \\ 5783 \\ 7604 \end{array}$	$     \begin{array}{r} T^{sol} \\     0.1s \\     0.1s \\     0.1s \\     0.2s \\     0.3s \\     \end{array} $
		Var 111 190 582 1398 2169 3120	$\begin{array}{c} M_{sun} \\ \hline Cnf \\ 455 \\ 924 \\ 2855 \\ 6232 \\ 8788 \\ 11749 \end{array}$	$     \begin{array}{r}       T^{sol} \\       0.1s \\       0.1s \\       0.2s \\       0.2s \\       0.5s \\       \hline       0.5s \\       \hline       \end{array} $	111 190 582 1306 1801 2296	$\begin{array}{r} Cnf \\ 440 \\ 879 \\ 2722 \\ 5783 \\ 7604 \\ 9425 \end{array}$	$\begin{array}{c} T^{sol} \\ 0.1s \\ 0.1s \\ 0.1s \\ 0.2s \\ 0.3s \\ 0.5s \end{array}$
	$ \begin{array}{c} 0 \\ 0 \\ -1 \\ -3 \\ -5 \\ -7 \\ -9 \\ \end{array} $	Var 111 190 582 1398 2169 3120 4251	$\begin{array}{r} M_{sun} \\ Cnf \\ 455 \\ 924 \\ 2855 \\ 6232 \\ 8788 \\ 11749 \\ 15115 \end{array}$	$\begin{array}{c} T^{sol} \\ 0.1s \\ 0.1s \\ 0.2s \\ 0.2s \\ 0.2s \\ 0.5s \\ 1.1s \end{array}$	111 190 582 1306 1801 2296 2791	$\begin{array}{c} Cnf \\ 440 \\ 879 \\ 2722 \\ 5783 \\ 7604 \\ 9425 \\ 11246 \end{array}$	$\begin{array}{c} T^{sol} \\ 0.1s \\ 0.1s \\ 0.2s \\ 0.3s \\ 0.5s \\ 0.8s \end{array}$
$     \begin{array}{r}       1 \\       2 \\       3 \\       4 \\       5 \\       6 \\       7 \\       8 \\       8       \end{array} $	$ \begin{array}{c} 0 \\ 0 \\ -1 \\ -3 \\ -5 \\ -7 \\ -9 \\ -12 \end{array} $	$\begin{tabular}{ c c c c c c c c c c c c c c c c c c c$	$\begin{array}{r} M_{sun} \\ Cnf \\ 455 \\ 924 \\ 2855 \\ 6232 \\ 8788 \\ 11749 \\ 15115 \\ 25655 \end{array}$	$\begin{array}{c} T^{sol} \\ 0.1s \\ 0.1s \\ 0.1s \\ 0.2s \\ 0.2s \\ 0.2s \\ 1.1s \\ 3.8s \end{array}$	111 190 582 1306 1801 2296 2791 4614	$\begin{array}{c} Cnf \\ 440 \\ 879 \\ 2722 \\ 5783 \\ 7604 \\ 9425 \\ 11246 \\ 17884 \end{array}$	$\begin{array}{c} T^{sol} \\ 0.1s \\ 0.1s \\ 0.2s \\ 0.3s \\ 0.5s \\ 0.8s \\ 3.9s \end{array}$
$     \begin{array}{r}       1 \\       2 \\       3 \\       4 \\       5 \\       6 \\       7 \\       8 \\       9 \\       9     \end{array} $	$ \begin{array}{r} 0 \\ 0 \\ -1 \\ -3 \\ -5 \\ -7 \\ -9 \\ -12 \\ -14 \\ \end{array} $	$\begin{array}{c} Var \\ 111 \\ 190 \\ 582 \\ 1398 \\ 2169 \\ 3120 \\ 4251 \\ 7654 \\ 7455 \end{array}$	$\begin{array}{r} M_{sun} \\ Cnf \\ 455 \\ 924 \\ 2855 \\ 6232 \\ 8788 \\ 11749 \\ 15115 \\ 25655 \\ 23863 \end{array}$	$\begin{array}{c} T^{sol} \\ 0.1s \\ 0.1s \\ 0.2s \\ 0.2s \\ 0.2s \\ 1.1s \\ 3.8s \\ 10.8s \end{array}$	111 190 582 1306 1801 2296 2791 4614 4081	$\begin{array}{c} Cnf \\ 440 \\ 879 \\ 2722 \\ 5783 \\ 7604 \\ 9425 \\ 11246 \\ 17884 \\ 15482 \end{array}$	$\begin{array}{c} T^{sol} \\ 0.1s \\ 0.1s \\ 0.2s \\ 0.3s \\ 0.5s \\ 0.8s \\ 3.9s \\ 6.1s \end{array}$
$     \begin{array}{r}       1 \\       2 \\       3 \\       4 \\       5 \\       6 \\       7 \\       8 \\       9 \\       10 \\       10 \\       \end{array} $	$ \begin{array}{c} 0\\ -1\\ -3\\ -5\\ -7\\ -9\\ -12\\ -14\\ -17\\ \end{array} $	$\begin{array}{c} Var \\ 111 \\ 190 \\ 582 \\ 1398 \\ 2169 \\ 3120 \\ 4251 \\ 7654 \\ 7455 \\ 12526 \end{array}$	$\begin{array}{r} M_{sun} \\ Cnf \\ 455 \\ 924 \\ 2855 \\ 6232 \\ 8788 \\ 11749 \\ 15115 \\ 25655 \\ 23863 \\ 38639 \end{array}$	$\begin{array}{c} T^{sol} \\ 0.1s \\ 0.1s \\ 0.2s \\ 0.2s \\ 0.2s \\ 0.5s \\ 1.1s \\ 3.8s \\ 10.8s \\ 46.1s \end{array}$	$\begin{array}{c} 111\\ 190\\ 582\\ 1306\\ 1801\\ 2296\\ 2791\\ 4614\\ 4081\\ 6334\\ \end{array}$	$\begin{array}{c} Cnf \\ 440 \\ 879 \\ 2722 \\ 5783 \\ 7604 \\ 9425 \\ 11246 \\ 17884 \\ 15482 \\ 23532 \end{array}$	$\begin{array}{c} T^{sol} \\ 0.1s \\ 0.1s \\ 0.2s \\ 0.3s \\ 0.5s \\ 0.8s \\ 3.9s \\ 6.1s \\ 28.8s \end{array}$
$ \begin{array}{c} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \\ 9 \\ 10 \\ 11 \end{array} $	0 0 -1 -3 -5 -7 -9 -12 -12 -14 -17 -19	$\begin{array}{c} Var \\ 111 \\ 190 \\ 582 \\ 1398 \\ 2169 \\ 3120 \\ 4251 \\ 7654 \\ 7455 \\ 12526 \\ 11559 \end{array}$	$\begin{array}{c} M_{sun} \\ Cnf \\ 455 \\ 924 \\ 2855 \\ 6232 \\ 8788 \\ 11749 \\ 15115 \\ 25655 \\ 23863 \\ 38639 \\ 34591 \end{array}$	$\begin{array}{c} T^{sol} \\ \hline 0.1s \\ 0.1s \\ 0.2s \\ 0.2s \\ 0.2s \\ 0.5s \\ 1.1s \\ 3.8s \\ 10.8s \\ 46.1s \\ 48.4s \end{array}$	$\begin{array}{c} 111\\ 190\\ 582\\ 1306\\ 1801\\ 2296\\ 2791\\ 4614\\ 4081\\ 6334\\ 5371\\ \end{array}$	$\begin{array}{c} Cnf \\ 440 \\ 879 \\ 2722 \\ 5783 \\ 7604 \\ 9425 \\ 11246 \\ 17884 \\ 15482 \\ 23532 \\ 19718 \end{array}$	$\begin{array}{c} T^{sol} \\ 0.1s \\ 0.1s \\ 0.2s \\ 0.3s \\ 0.5s \\ 0.8s \\ 3.9s \\ 6.1s \\ 28.8s \\ 37.6s \end{array}$
$ \begin{array}{c} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \\ 9 \\ 10 \\ 11 \\ 12 \\ \end{array} $	$\begin{array}{c} 0 \\ 0 \\ -1 \\ -3 \\ -5 \\ -7 \\ -9 \\ -12 \\ -14 \\ -17 \\ -19 \\ -20 \\ \end{array}$	$\begin{array}{c} Var \\ 111 \\ 190 \\ 582 \\ 1398 \\ 2169 \\ 3120 \\ 4251 \\ 7654 \\ 7455 \\ 12526 \\ 11559 \\ 8941 \end{array}$	$\begin{array}{c} M_{sun} \\ Cnf \\ 455 \\ 924 \\ 2855 \\ 6232 \\ 8788 \\ 11749 \\ 15115 \\ 25655 \\ 23863 \\ 38639 \\ 34591 \\ 26418 \end{array}$	$\begin{array}{c} T^{sol} \\ \hline 0.1s \\ 0.1s \\ 0.2s \\ 0.2s \\ 0.5s \\ 1.1s \\ 3.8s \\ 10.8s \\ 46.1s \\ 48.4s \\ 17.0s \end{array}$	$\begin{array}{c} 111\\ 190\\ 582\\ 1306\\ 1801\\ 2296\\ 2791\\ 4614\\ 4081\\ 6334\\ 5371\\ 3673\\ \end{array}$	$\begin{array}{c} Cnf \\ 440 \\ 879 \\ 2722 \\ 5783 \\ 7604 \\ 9425 \\ 11246 \\ 17884 \\ 15482 \\ 23532 \\ 19718 \\ 13886 \end{array}$	$\begin{array}{c} T^{sol} \\ 0.1s \\ 0.1s \\ 0.2s \\ 0.3s \\ 0.5s \\ 0.8s \\ 3.9s \\ 6.1s \\ 28.8s \\ 37.6s \\ 30.0s \end{array}$
$     \begin{array}{r}       1 \\       2 \\       3 \\       4 \\       5 \\       6 \\       7 \\       7 \\       8 \\       9 \\       10 \\       11 \\       12 \\       13 \\       13 \\       \end{array} $	$\begin{array}{c} 0 \\ 0 \\ -1 \\ -3 \\ -5 \\ -7 \\ -9 \\ -12 \\ -14 \\ -17 \\ -19 \\ -20 \\ -22 \\ \end{array}$	$\begin{array}{c} Var \\ 111 \\ 190 \\ 582 \\ 2169 \\ 3120 \\ 4251 \\ 7654 \\ 7455 \\ 12526 \\ 11559 \\ 8941 \\ 15399 \end{array}$	$\begin{array}{c} M_{sun} \\ Cnf \\ 455 \\ 924 \\ 2855 \\ 6232 \\ 8788 \\ 11749 \\ 15115 \\ 25655 \\ 23863 \\ 38639 \\ 34591 \\ 26418 \\ 44977 \end{array}$	$\begin{array}{c} T^{sol} \\ \hline 0.1s \\ 0.1s \\ 0.2s \\ 0.2s \\ 0.5s \\ 1.1s \\ 3.8s \\ 10.8s \\ 46.1s \\ 48.4s \\ 17.0s \\ 41.7s \end{array}$	$\begin{array}{c} 111\\ 190\\ 582\\ 1306\\ 1801\\ 2296\\ 2791\\ 4614\\ 4081\\ 6334\\ 5371\\ 3673\\ 5695\\ \end{array}$	$\begin{array}{c} Cnf \\ 440 \\ 879 \\ 2722 \\ 5783 \\ 7604 \\ 9425 \\ 11246 \\ 17884 \\ 15482 \\ 23532 \\ 19718 \\ 13886 \\ 22034 \end{array}$	$\begin{array}{c} T^{sol} \\ 0.1s \\ 0.1s \\ 0.2s \\ 0.3s \\ 0.5s \\ 0.8s \\ 3.9s \\ 6.1s \\ 28.8s \\ 37.6s \\ 30.0s \\ 25.9s \end{array}$
$     \begin{array}{r}       1 \\       2 \\       3 \\       4 \\       5 \\       6 \\       7 \\       8 \\       9 \\       10 \\       11 \\       12 \\       13 \\       14 \\       14 \\       14 \\       12 \\       13 \\       11$	$\begin{array}{c} 0\\ 0\\ -1\\ -3\\ -5\\ -7\\ -9\\ -12\\ -14\\ -17\\ -19\\ -20\\ -22\\ -24\\ \end{array}$	Var 111 190 582 1398 2169 3120 4251 7654 7455 12526 11559 8941 15399 17835	$\begin{array}{c} M_{sun} \\ Cnf \\ 455 \\ 924 \\ 2855 \\ 6232 \\ 8788 \\ 11749 \\ 15115 \\ 25655 \\ 23863 \\ 38639 \\ 34591 \\ 26418 \\ 44977 \\ 51268 \end{array}$	$\begin{array}{c} T^{sol} \\ 0.1s \\ 0.1s \\ 0.2s \\ 0.2s \\ 0.2s \\ 0.5s \\ 1.1s \\ 3.8s \\ 10.8s \\ 46.1s \\ 48.4s \\ 17.0s \\ 41.7s \\ 12.8s \end{array}$	$\begin{array}{c} 111\\ 190\\ 582\\ 1306\\ 1801\\ 2296\\ 2791\\ 4614\\ 6334\\ 5371\\ 3673\\ 5695\\ 6145\\ \end{array}$	$\begin{array}{c} Cnf \\ 440 \\ 879 \\ 2722 \\ 5783 \\ 7604 \\ 9425 \\ 11246 \\ 17884 \\ 15482 \\ 23532 \\ 19718 \\ 13886 \\ 22034 \\ 23765 \end{array}$	$\begin{array}{c} T^{sol} \\ 0.1s \\ 0.1s \\ 0.2s \\ 0.3s \\ 0.2s \\ 0.3s \\ 0.5s \\ 0.8s \\ 3.9s \\ 6.1s \\ 28.8s \\ 37.6s \\ 30.0s \\ 25.9s \\ 26.4s \end{array}$
$     \begin{array}{r}       1 \\       2 \\       3 \\       4 \\       5 \\       6 \\       7 \\       8 \\       9 \\       10 \\       11 \\       12 \\       13 \\       14 \\       15 \\       \end{array} $	$\begin{array}{c} 0\\ 0\\ -1\\ -3\\ -5\\ -7\\ -9\\ -12\\ -14\\ -17\\ -19\\ -20\\ -22\\ -24\\ -26\\ \end{array}$	$\begin{array}{c} Var \\ 111 \\ 190 \\ 582 \\ 1398 \\ 2169 \\ 3120 \\ 4251 \\ 7654 \\ 7455 \\ 12526 \\ 11559 \\ 8941 \\ 15399 \\ 17835 \\ 20451 \end{array}$	$\begin{array}{c} M_{sun} \\ Cnf \\ 455 \\ 924 \\ 2855 \\ 6232 \\ 8788 \\ 11749 \\ 15115 \\ 25655 \\ 23863 \\ 38639 \\ 34591 \\ 26418 \\ 44977 \\ 51268 \\ 57964 \end{array}$	$\begin{array}{c} T^{sol} \\ 0.1s \\ 0.1s \\ 0.2s \\ 0.2s \\ 0.2s \\ 0.5s \\ 1.1s \\ 3.8s \\ 10.8s \\ 46.1s \\ 48.4s \\ 17.0s \\ 41.7s \\ 12.8s \\ 15.8s \\ \end{array}$	$\begin{array}{c} 111\\ 190\\ 582\\ 1306\\ 1801\\ 2296\\ 2791\\ 4614\\ 4081\\ 6334\\ 5371\\ 3673\\ 5695\\ 6145\\ 6595\\ \end{array}$	$\begin{array}{c} Cnf \\ 440 \\ 879 \\ 2722 \\ 5783 \\ 7604 \\ 9425 \\ 11246 \\ 17884 \\ 15482 \\ 23532 \\ 19718 \\ 13886 \\ 22034 \\ 22034 \\ 223765 \\ 25496 \end{array}$	$\begin{array}{c} T^{sol} \\ 0.1s \\ 0.1s \\ 0.1s \\ 0.2s \\ 0.3s \\ 0.5s \\ 0.8s \\ 3.9s \\ 6.1s \\ 28.8s \\ 37.6s \\ 30.0s \\ 25.9s \\ 26.4s \\ 23.2s \end{array}$
$     \begin{array}{r}       1 \\       2 \\       3 \\       4 \\       5 \\       6 \\       7 \\       8 \\       9 \\       10 \\       11 \\       12 \\       13 \\       14 \\       15 \\       16 \\       \end{array} $	$\begin{array}{c} 0 \\ 0 \\ -1 \\ -3 \\ -5 \\ -7 \\ -9 \\ -12 \\ -14 \\ -17 \\ -19 \\ -20 \\ -22 \\ -24 \\ -26 \\ -28 \end{array}$	Var 111 190 582 1398 2169 3120 4251 7455 7455 12526 11559 8941 15399 17835 20451 23247	$\begin{array}{c} M_{sun} \\ Cnf \\ 455 \\ 924 \\ 2855 \\ 6232 \\ 8788 \\ 11749 \\ 15115 \\ 25655 \\ 23863 \\ 38639 \\ 34591 \\ 26418 \\ 44977 \\ 51268 \\ 57964 \\ 65065 \end{array}$	$\begin{array}{c} T^{sol} \\ \hline 0.1s \\ 0.1s \\ 0.2s \\ 0.2s \\ 0.2s \\ 0.5s \\ 1.1s \\ 3.8s \\ 10.8s \\ 46.1s \\ 48.4s \\ 17.0s \\ 41.7s \\ 12.8s \\ 15.8s \\ 38.9s \\ \end{array}$	$\begin{array}{c} 111\\ 190\\ 582\\ 1306\\ 1801\\ 2296\\ 2791\\ 4614\\ 4081\\ 6334\\ 5371\\ 3673\\ 5695\\ 6145\\ 7045\\ \end{array}$	$\begin{array}{c} Cnf \\ 440 \\ 879 \\ 2722 \\ 5783 \\ 7604 \\ 9425 \\ 11246 \\ 17884 \\ 123532 \\ 19718 \\ 13886 \\ 22034 \\ 23765 \\ 25496 \\ 25496 \\ 25427 \end{array}$	$\begin{array}{c} T^{sol} \\ 0.1s \\ 0.1s \\ 0.1s \\ 0.2s \\ 0.3s \\ 0.5s \\ 0.8s \\ 0.5s \\ 0.8s \\ 3.9s \\ 6.1s \\ 28.8s \\ 37.6s \\ 30.0s \\ 25.9s \\ 26.4s \\ 23.2s \\ 35.7s \end{array}$
$ \begin{array}{c} 1\\2\\3\\4\\5\\6\\7\\7\\8\\9\\10\\11\\12\\13\\14\\15\\16\\17\end{array}$	$\begin{array}{c} 0 \\ 0 \\ -1 \\ -3 \\ -5 \\ -7 \\ -9 \\ -12 \\ -14 \\ -17 \\ -19 \\ -20 \\ -22 \\ -24 \\ -22 \\ -24 \\ -26 \\ -28 \\ -30 \\ \end{array}$	Var 111 190 582 2169 3120 4251 7655 12526 11559 8941 15399 17835 20451 23247 26223	$\begin{array}{c} M_{sun} \\ Cnf \\ 455 \\ 924 \\ 2855 \\ 6232 \\ 8788 \\ 11749 \\ 15115 \\ 25655 \\ 23863 \\ 38639 \\ 34591 \\ 26418 \\ 44977 \\ 51268 \\ 57964 \\ 65065 \\ 72571 \end{array}$	$\begin{array}{c} T^{sol} \\ 0.1s \\ 0.1s \\ 0.2s \\ 0.2s \\ 0.5s \\ 1.1s \\ 3.8s \\ 10.8s \\ 46.1s \\ 48.4s \\ 17.0s \\ 41.7s \\ 12.8s \\ 15.8s \\ 15.8s \\ 38.9s \\ 62.2s \end{array}$	$\begin{array}{c} 111\\ 190\\ 582\\ 1306\\ 1801\\ 2296\\ 2791\\ 4614\\ 4081\\ 6334\\ 5371\\ 3673\\ 5695\\ 6145\\ 7045\\ 7495\\ \end{array}$	$\begin{array}{c} Cnf \\ 440 \\ 879 \\ 2722 \\ 5783 \\ 7604 \\ 9425 \\ 11246 \\ 17884 \\ 15482 \\ 23532 \\ 19718 \\ 13886 \\ 2034 \\ 23765 \\ 25496 \\ 27227 \\ 28958 \end{array}$	$\begin{array}{c} T^{sol} \\ 0.1s \\ 0.1s \\ 0.2s \\ 0.2s \\ 0.3s \\ 0.5s \\ 0.8s \\ 3.9s \\ 6.1s \\ 28.8s \\ 37.6s \\ 30.0s \\ 25.9s \\ 26.4s \\ 23.2s \\ 35.7s \\ 31.7s \end{array}$
$ \begin{array}{c} 1\\2\\3\\4\\5\\6\\7\\7\\8\\9\\10\\11\\12\\13\\14\\15\\16\\17\\18\end{array}$	$\begin{array}{c} 0\\ 0\\ -1\\ -3\\ -5\\ -7\\ -9\\ -12\\ -14\\ -17\\ -19\\ -20\\ -22\\ -24\\ -26\\ -28\\ -30\\ -34\\ \end{array}$	Var 111 190 582 2169 3120 4251 7654 7455 12526 1559 8941 15399 17835 20451 23247 26223 50310	$\begin{array}{c} M_{sun} \\ Cnf \\ 455 \\ 924 \\ 2855 \\ 6232 \\ 8788 \\ 11749 \\ 15115 \\ 25655 \\ 23863 \\ 38639 \\ 34591 \\ 26418 \\ 44977 \\ 51268 \\ 57964 \\ 65065 \\ 57964 \\ 65065 \\ 72571 \\ 136821 \end{array}$	$\begin{array}{c} T^{sol} \\ \hline 0.1s \\ 0.1s \\ 0.2s \\ 0.2s \\ 0.5s \\ 1.1s \\ 3.8s \\ 10.8s \\ 46.1s \\ 48.4s \\ 17.0s \\ 41.7s \\ 12.8s \\ 15.8s \\ 38.9s \\ 62.2s \\ 1315.2s \end{array}$	$\begin{array}{c} 111\\ 190\\ 582\\ 1306\\ 1801\\ 2296\\ 2791\\ 4614\\ 4081\\ 6334\\ 5371\\ 3673\\ 5695\\ 6145\\ 6595\\ 7045\\ 7495\\ 14570\\ \end{array}$	$\begin{array}{c} Cnf \\ 440 \\ 879 \\ 2722 \\ 5783 \\ 7604 \\ 9425 \\ 11246 \\ 17884 \\ 15482 \\ 23532 \\ 23532 \\ 23532 \\ 23532 \\ 23532 \\ 22034 \\ 23765 \\ 22034 \\ 23765 \\ 25496 \\ 27227 \\ 28958 \\ 53795 \end{array}$	$\begin{array}{c} T^{sol} \\ 0.1s \\ 0.1s \\ 0.2s \\ 0.2s \\ 0.3s \\ 0.5s \\ 0.8s \\ 3.9s \\ 6.1s \\ 28.8s \\ 37.6s \\ 30.0s \\ 25.9s \\ 26.4s \\ 23.2s \\ 33.7s \\ 33.7s \\ 622.0s \end{array}$
$\begin{array}{c} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \\ 9 \\ 10 \\ 11 \\ 12 \\ 13 \\ 14 \\ 15 \\ 16 \\ 17 \\ 18 \\ 19 \\ \end{array}$	$\begin{array}{c} 0\\ 0\\ -1\\ -3\\ -5\\ -7\\ -9\\ -12\\ -14\\ -17\\ -19\\ -20\\ -22\\ -24\\ -26\\ -28\\ -30\\ -34\\ -36\\ \end{array}$	Var 111 190 582 1398 2169 3120 4251 7654 7455 12526 11559 8941 15399 17835 20451 23247 26232 50310 34419	$\begin{array}{c} M_{sun} \\ Cnf \\ 455 \\ 924 \\ 2855 \\ 6232 \\ 8788 \\ 11749 \\ 15115 \\ 25655 \\ 23863 \\ 38639 \\ 34591 \\ 26418 \\ 44977 \\ 51268 \\ 57964 \\ 65065 \\ 72571 \\ 136821 \\ 92200 \end{array}$	$\begin{array}{c} T^{sol} \\ 0.1s \\ 0.1s \\ 0.2s \\ 0.2s \\ 0.5s \\ 1.1s \\ 3.8s \\ 10.8s \\ 46.1s \\ 48.4s \\ 17.0s \\ 41.7s \\ 12.8s \\ 15.8s \\ 38.9s \\ 62.2s \\ 1315.2s \\ 1346.1s \end{array}$	$\begin{array}{c} 111\\ 190\\ 582\\ 1306\\ 1801\\ 2296\\ 2791\\ 4614\\ 4081\\ 6334\\ 5371\\ 3673\\ 5695\\ 6145\\ 6595\\ 7045\\ 7495\\ 7495\\ 7495\\ 7495\\ 9889\\ \end{array}$	$\begin{array}{c} Cnf \\ 440 \\ 879 \\ 2722 \\ 5783 \\ 7604 \\ 9425 \\ 11246 \\ 17884 \\ 15482 \\ 23532 \\ 19718 \\ 13886 \\ 22034 \\ 22034 \\ 22034 \\ 2277 \\ 28958 \\ 53795 \\ 35396 \end{array}$	$\begin{array}{c} T^{sol} \\ 0.1s \\ 0.1s \\ 0.1s \\ 0.2s \\ 0.3s \\ 0.5s \\ 0.8s \\ 3.9s \\ 3.9s \\ 3.9s \\ 3.9s \\ 28.8s \\ 37.6s \\ 30.0s \\ 25.9s \\ 26.4s \\ 23.2s \\ 35.7s \\ 31.7s \\ 622.0s \\ 1578.2s \\ 1578.2s \\ \end{array}$
$\begin{array}{c} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \\ 9 \\ 10 \\ 11 \\ 12 \\ 13 \\ 14 \\ 15 \\ 16 \\ 17 \\ 18 \\ 19 \\ 20 \end{array}$	$\begin{array}{c} 0\\ 0\\ -1\\ -3\\ -5\\ -7\\ -9\\ -12\\ -14\\ -17\\ -19\\ -20\\ -22\\ -24\\ -26\\ -28\\ -30\\ -38\\ -36\\ -38\\ \end{array}$	Var 111 190 582 1398 2169 3120 4251 7654 7455 12526 11559 8941 15399 17835 20451 23247 26223 50310 34419 38025	$\begin{array}{r} M_{sun} \\ Cnf \\ 455 \\ 924 \\ 2855 \\ 6232 \\ 8788 \\ 11749 \\ 15115 \\ 25655 \\ 23863 \\ 38639 \\ 34591 \\ 26418 \\ 44977 \\ 51268 \\ 57964 \\ 65065 \\ 72571 \\ 136821 \\ 92200 \\ 101101 \end{array}$	$\begin{array}{c} T^{sol} \\ 0.1s \\ 0.1s \\ 0.2s \\ 0.2s \\ 0.2s \\ 0.5s \\ 1.1s \\ 3.8s \\ 10.8s \\ 46.1s \\ 48.4s \\ 17.0s \\ 41.7s \\ 12.8s \\ 15.8s \\ 38.9s \\ 62.2s \\ 1315.2s \\ 1346.1s \\ 2133.8s \end{array}$	$\begin{array}{c} 111\\ 190\\ 582\\ 1306\\ 1801\\ 2296\\ 2791\\ 4614\\ 4081\\ 6334\\ 5371\\ 3673\\ 5695\\ 6145\\ 6595\\ 7045\\ 7495\\ 14570\\ 9889\\ 10249\\ \end{array}$	$\begin{array}{c} Cnf \\ 440 \\ 879 \\ 2722 \\ 5783 \\ 7604 \\ 9425 \\ 11246 \\ 17884 \\ 15482 \\ 23532 \\ 19718 \\ 13886 \\ 22034 \\ 23765 \\ 22034 \\ 23765 \\ 25496 \\ 27227 \\ 28958 \\ 53795 \\ 35396 \\ 36947 \end{array}$	$\begin{array}{c} T^{sol} \\ 0.1s \\ 0.1s \\ 0.1s \\ 0.2s \\ 0.3s \\ 0.5s \\ 0.8s \\ 3.9s \\ 0.5s \\ 3.9s \\ 3.9s \\ 28.8s \\ 37.6s \\ 30.0s \\ 25.9s \\ 25.9s \\ 26.4s \\ 23.2s \\ 35.7s \\ 31.7s \\ 622.0s \\ 1578.2s \\ 1578.2s \\ 1549.7s \\ 25.9s \\ 25.9s$
$\begin{array}{c} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \\ 9 \\ 10 \\ 11 \\ 12 \\ 13 \\ 14 \\ 15 \\ 16 \\ 17 \\ 18 \\ 19 \\ 20 \\ 21 \\ \end{array}$	$\begin{array}{c} 0\\ 0\\ -1\\ -3\\ -5\\ -7\\ -9\\ -12\\ -14\\ -17\\ -19\\ -20\\ -22\\ -24\\ -26\\ -28\\ -30\\ -34\\ -36\\ -38\\ -40\\ \end{array}$	$\begin{array}{r} Var \\ 111 \\ 190 \\ 582 \\ 1398 \\ 2169 \\ 3120 \\ 4251 \\ 7455 \\ 7455 \\ 12526 \\ 11559 \\ 8941 \\ 15399 \\ 17835 \\ 20451 \\ 23247 \\ 26223 \\ 50310 \\ 34025 \\ 41811 \\ \end{array}$	$\begin{array}{c} M_{sun} \\ Cnf \\ 455 \\ 924 \\ 2855 \\ 6232 \\ 8788 \\ 11749 \\ 15115 \\ 25655 \\ 23863 \\ 38639 \\ 34591 \\ 26418 \\ 44977 \\ 51268 \\ 57964 \\ 65065 \\ 72571 \\ 136821 \\ 92200 \\ 101101 \\ 110407 \end{array}$	$\begin{array}{c} T^{sol} \\ \hline 0.1s \\ 0.1s \\ 0.2s \\ 0.2s \\ 0.2s \\ 0.5s \\ 1.1s \\ 3.8s \\ 10.8s \\ 46.1s \\ 48.4s \\ 17.0s \\ 41.7s \\ 41.7s \\ 12.8s \\ 15.8s \\ 38.9s \\ 62.2s \\ 1315.2s \\ 1346.1s \\ 2133.8s \\ 1227.7s \end{array}$	$\begin{array}{c} 111\\ 190\\ 582\\ 1306\\ 2791\\ 4614\\ 4081\\ 5371\\ 3673\\ 5695\\ 6145\\ 6595\\ 7045\\ 7495\\ 14570\\ 9889\\ 10249\\ 10609\\ \end{array}$	$\begin{array}{c} Cnf \\ 440 \\ 879 \\ 2722 \\ 5783 \\ 7604 \\ 9425 \\ 11246 \\ 17884 \\ 123532 \\ 19718 \\ 13886 \\ 22034 \\ 23765 \\ 25496 \\ 27227 \\ 28958 \\ 53795 \\ 35396 \\ 35996 \\ 35996 \\ 35996 \\ 36947 \\ 38498 \end{array}$	$\begin{array}{c} T^{sol} \\ \hline T^{sol} \\ 0.1s \\ 0.1s \\ 0.2s \\ 0.3s \\ 0.5s \\ 0.8s \\ 0.5s \\ 0.8s \\ 3.9s \\ 0.5s \\ 3.9s \\ 28.8s \\ 37.6s \\ 30.0s \\ 25.9s \\ 26.4s \\ 23.2s \\ 35.7s \\ 31.7s \\ 622.0s \\ 1578.2s \\ 1578.2s \\ 1549.7s \\ 1549.7s \\ 1518.5s \\ \end{array}$
$\begin{array}{c} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \\ 9 \\ 10 \\ 11 \\ 12 \\ 13 \\ 14 \\ 15 \\ 16 \\ 17 \\ 18 \\ 19 \\ 20 \end{array}$	$\begin{array}{c} 0\\ 0\\ -1\\ -3\\ -5\\ -7\\ -9\\ -12\\ -14\\ -17\\ -19\\ -20\\ -22\\ -24\\ -26\\ -28\\ -30\\ -38\\ -36\\ -38\\ \end{array}$	Var 111 190 582 1398 2169 3120 4251 7654 7455 12526 11559 8941 15399 17835 20451 23247 26223 50310 34419 38025	$\begin{array}{r} M_{sun} \\ Cnf \\ 455 \\ 924 \\ 2855 \\ 6232 \\ 8788 \\ 11749 \\ 15115 \\ 25655 \\ 23863 \\ 38639 \\ 34591 \\ 26418 \\ 44977 \\ 51268 \\ 57964 \\ 65065 \\ 72571 \\ 136821 \\ 92200 \\ 101101 \end{array}$	$\begin{array}{c} T^{sol} \\ 0.1s \\ 0.1s \\ 0.2s \\ 0.2s \\ 0.2s \\ 0.5s \\ 1.1s \\ 3.8s \\ 10.8s \\ 46.1s \\ 48.4s \\ 17.0s \\ 41.7s \\ 12.8s \\ 15.8s \\ 38.9s \\ 62.2s \\ 1315.2s \\ 1346.1s \\ 2133.8s \end{array}$	$\begin{array}{c} 111\\ 190\\ 582\\ 1306\\ 1801\\ 2296\\ 2791\\ 4614\\ 4081\\ 6334\\ 5371\\ 3673\\ 5695\\ 6145\\ 6595\\ 7045\\ 7495\\ 14570\\ 9889\\ 10249\\ \end{array}$	$\begin{array}{c} Cnf \\ 440 \\ 879 \\ 2722 \\ 5783 \\ 7604 \\ 9425 \\ 11246 \\ 17884 \\ 15482 \\ 23532 \\ 19718 \\ 13886 \\ 22034 \\ 23765 \\ 22034 \\ 23765 \\ 25496 \\ 27227 \\ 28958 \\ 53795 \\ 35396 \\ 36947 \end{array}$	$\begin{array}{c} T^{sol} \\ 0.1s \\ 0.1s \\ 0.1s \\ 0.2s \\ 0.3s \\ 0.5s \\ 0.8s \\ 3.9s \\ 0.5s \\ 3.9s \\ 3.9s \\ 28.8s \\ 37.6s \\ 30.0s \\ 25.9s \\ 25.9s \\ 26.4s \\ 23.2s \\ 35.7s \\ 31.7s \\ 622.0s \\ 1578.2s \\ 1578.2s \\ 1549.7s \\ 25.9s \\ 25.9s$

 Table 10. Experimental results of SPECK32

Differential Property								
D 1	1 D	M <sub>sun</sub>			$M_{sim}$			
Round	$\log_2 P_{opt}$	Var	Cnf	$T^{sol}$	Var	Cnf	$T^{sol}$	
1	0	119	446	0.1s	119	423	0.1s	
2	-1	425	1869	0.3s	425	1778	0.1s	
3	-3	1191	4810	0.5s	1051	4325	0.2s	
4	-6	2966	10551	0.8s	2214	8492	0.3s	
5	-10	6575	20761	1.9s	4215	14875	1.3s	
6	-14	10590	30741	6.4s	5870	19545	2.9s	
7	-19	19110	52168	23.2s	9494	29980	18.4s	
8	-26	37868	97805	174.1s	17836	52472	155.2s	
9	-33	54112	133941	1764.7s	24176	67280	2170.1s	
10	-40	72932	175413	15030.6s	30516	82088	15476.6s	
11	-45	69234	163648	18668.9s	26174	69748	19057.5s	
12	-49	69125	161871	11095.6s	22805	61465	9322.1s	
13	-54	97908	227464	20309.8s	28712	78076	16776.3s	
14	-58	95090	219421	4787.1s	24920	68405	3966.3s	
15	-63	131550	301768	22354.6s	31250	86404	14627.8 s	
16	-68	151335	345052	31069.3s	33527	92578	17658.7s	
17	-75	233120	527877	214052.9s	50800	137776	198543.5s	
18	-82	269972	606885	692164.7s	59716	157736	568723.1s	
Total		1323222	3082491	1031574.8s	373820	1033446	866500.5s	
19	-89	-	-	-	68632	177696	1736050.9s	
David	lan Can		Linear M <sub>sun</sub>	Property		$M_{sim}$		
Round	$\log_2 Cor_{opt}$	Var	Cnf	$T^{sol}$	Var	Cnf	$T^{sol}$	
1	0	167	695	0.1s	167	672	0.1s	
2	0	286	1412	0.2s	286	1343	0.1s	
3	-1	878	4367	0.4s	878	4162	0.2s	
4	-3	2118	9544	0.4s	1978	8855	0.3s	
5	-6	4624	18411	0.6s	3872	15988	0.5s	
6	-8	5163	18832	1.4s	3757	14981	1.0s	
7	-12	12405	41821	21.8s	8195	30970	10.4s	
8	-15	13882	43731	79.5s	8266	29900	63.8s	
9	-19	23105	69231	1190.9s	12595	44030	1303.9s	
10	-22	23730	68419	3425.5s	11786	40348	3016.2s	
11								
	-25	29116	81827	13328.0s	13100	44684	12381.6s	
12	-25 -28		81827 96431	13328.0s 23989.9s	$\frac{13100}{14414}$	44684 49020	12381.6s 21814.9s	
		29116						
12	-28	29116 35054	96431	23989.9s	14414	49020	21814.9s	
12 13	-28 -30	29116 35054 30711	96431 83281	23989.9s 11245.4s	$14414 \\ 11353$	49020 39134	21814.9s 8996.6s	
12 13 14	-28 -30 -33	29116 35054 30711 47302	96431 83281 126663	23989.9s 11245.4s 36999.4s	14414 11353 15958	49020 39134 55532	21814.9s 8996.6s 28682.4s	
12 13 14 15	-28 -30 -33 -37	29116 35054 30711 47302 69365	96431 83281 126663 182556	23989.9s 11245.4s 36999.4s 144397.5s	14414 11353 15958 22555	49020 39134 55532 76760	21814.9s 8996.6s 28682.4s 131326.2s	
$     \begin{array}{r}       12 \\       13 \\       14 \\       15 \\       16     \end{array} $	-28 -30 -33 -37 -39 -43 -45	29116 35054 30711 47302 69365 47694	96431 83281 126663 182556 124006	23989.9s 11245.4s 36999.4s 144397.5s 105626.1s	14414 11353 15958 22555 14476	49020 39134 55532 76760 49223	21814.9s 8996.6s 28682.4s 131326.2s 90098.0s	
$     \begin{array}{r}       12 \\       13 \\       14 \\       15 \\       16 \\       17 \\       \end{array} $	-28 -30 -33 -37 -39 -43 -45 -48	29116 35054 30711 47302 69365 47694 90305	96431 83281 126663 182556 124006 232291	$\begin{array}{r} 23989.9 \mathrm{s} \\ 11245.4 \mathrm{s} \\ 36999.4 \mathrm{s} \\ 144397.5 \mathrm{s} \\ 105626.1 \mathrm{s} \\ 449659.4 \mathrm{s} \end{array}$	14414 11353 15958 22555 14476 25945	49020 39134 55532 76760 49223 87810	21814.9s 8996.6s 28682.4s 131326.2s 90098.0s 382129.5s	
$     \begin{array}{r}       12 \\       13 \\       14 \\       15 \\       16 \\       17 \\       18 \\       \end{array} $	-28 -30 -33 -37 -39 -43 -45	29116 35054 30711 47302 69365 47694 90305 61086	96431 83281 126663 182556 124006 232291 155641	23989.9s 11245.4s 36999.4s 144397.5s 105626.1s 449659.4s 310300.9s	14414 11353 15958 22555 14476 25945 16510	49020 39134 55532 76760 49223 87810 55853	21814.9s 8996.6s 28682.4s 131326.2s 90098.0s 382129.5s 154346.7s	
$     \begin{array}{r}       12 \\       13 \\       14 \\       15 \\       16 \\       17 \\       18 \\       19 \\       19 \\       \end{array} $	-28 -30 -33 -37 -39 -43 -45 -48	$\begin{array}{c} 29116\\ 35054\\ 30711\\ 47302\\ 69365\\ 47694\\ 90305\\ 61086\\ 90332\\ \end{array}$	96431 83281 126663 182556 124006 232291 155641 228663	23989.9s 11245.4s 36999.4s 144397.5s 105626.1s 449659.4s 310300.9s 205234.8s	14414 11353 15958 22555 14476 25945 16510 22604	49020 39134 55532 76760 49223 87810 55853 77364	21814.9s 8996.6s 28682.4s 131326.2s 90098.0s 382129.5s 154346.7s 139713.7s	
$     \begin{array}{r}       12 \\       13 \\       14 \\       15 \\       16 \\       17 \\       18 \\       19 \\       20 \\       20 \\       \end{array} $	$ \begin{array}{r} -28 \\ -30 \\ -33 \\ -37 \\ -39 \\ -43 \\ -45 \\ -48 \\ -51 \\ \end{array} $	$\begin{array}{c} 29116\\ 35054\\ 30711\\ 47302\\ 69365\\ 47694\\ 90305\\ 61086\\ 90332\\ 100594 \end{array}$	96431 83281 126663 182556 124006 232291 155641 228663 252651	23989.9s 11245.4s 36999.4s 144397.5s 105626.1s 449659.4s 310300.9s 205234.8s 184329.7s	14414 11353 15958 22555 14476 25945 16510 22604 24010	49020 39134 55532 76760 49223 87810 55853 77364 81884	21814.9s 8996.6s 28682.4s 131326.2s 90098.0s 382129.5s 154346.7s 139713.7s 62696.2s	
$     \begin{array}{r}       12 \\       13 \\       14 \\       15 \\       16 \\       17 \\       18 \\       19 \\       20 \\       21 \\     \end{array} $	$\begin{array}{r} -28 \\ -30 \\ -33 \\ -37 \\ -39 \\ -43 \\ -43 \\ -45 \\ -48 \\ -51 \\ -54 \end{array}$	$\begin{array}{c} 29116\\ 35054\\ 30711\\ 47302\\ 69365\\ 47694\\ 90305\\ 61086\\ 90332\\ 100594\\ 111408\\ 122774\\ 100227\\ \end{array}$	96431 83281 126663 182556 124006 232291 155641 228663 252651 277835 304215 247261	$\begin{array}{r} 23989.9\mathrm{s} \\ 11245.4\mathrm{s} \\ 36999.4\mathrm{s} \\ 144397.5\mathrm{s} \\ 105626.1\mathrm{s} \\ 449659.4\mathrm{s} \\ 310300.9\mathrm{s} \\ 205234.8\mathrm{s} \\ 184329.7\mathrm{s} \\ 782536.3\mathrm{s} \end{array}$	$\begin{array}{r} 14414\\ 11353\\ 15958\\ 22555\\ 14476\\ 25945\\ 16510\\ 22604\\ 24010\\ 25416\\ 26822\\ 20383\\ \end{array}$	49020 39134 55532 76760 49223 87810 55853 77364 81884 86404	$\begin{array}{r} 21814.9s\\ 8996.6s\\ 28682.4s\\ 131326.2s\\ 90098.0s\\ 382129.5s\\ 154346.7s\\ 139713.7s\\ 62696.2s\\ 543774.3s\end{array}$	

 Table 11. Experimental results of SPECK48

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		D	ifferentia	l Propert	$\mathbf{y}$		
Round	$\log_2 P_{opt}$		$M_{sun}$			$M_{sim}$	
nouna	log <sub>2</sub> I opt	Var	Cnf	$T^{sol}$	Var	Cnf	$T^{sol}$
1	0	159	598	0.1s	159	567	0.1s
2	-1	569	2509	0.3s	569	2386	0.1s
3	-3	1599	6466	0.4s	1411	5813	0.2s
4	-6	3990	14199	1.0s	2982	11436	0.5s
5	-10	8855	27961	2.7s	5695	20075	2.4s
6	-15	17679	50812	15.8s	10079	32782	11.0s
7	-21	32319	86556	78.0s	16779	50841	78.6s
8	-29	62991	159427	1414.9s	30945	87369	1382.8s
9	-34	58056	142108	1954.5s	25640	70444	1665.8s
10	-38	60690	146291	1266.6s	23050	63905	1971.9s
11	-42	73545	175406	518.8s	24065	67775	551.8s
12	-46	87640	207156	524.9s	25080	71645	333.0s
13	-50	102975	241541	685.1s	26095	75515	508.7s
14	-56	170401	396040	1793.7s	40943	117103	1458.5s
15	-62	202055	464969	7300.5s	48083	133931	7970.2s
16	-70	308286	702316	171274.8s	75378	202569	124237.1s
17	-73	157152	355875	3821.9s	36120	96728	3618.4s
18	-76	173082	391331	2644.1s	33922	93812	1200.3s
18	-70	288162	649648	2044.1s 2777.5s	51086	143332	1200.3s 1894.5s
20	-81	266705	599311	2356.3s	43945	143332 124025	1623.7s
20	-85	200705	656946	2350.5s 1274.9s	43945	124025 125725	1023.7s 1064.8s
21 22	-89	386793	864742	1274.9s 1874.5s	43873 54593	156958	1004.8s 1809.3s
23	-99	425742	948952	4186.1s	58454	166876	3068.2s
24	-107	709857	1575649	53855.4s	103395	285009	43906.8s
25	-112	523152	1156936	40157.5s	78776	211876	36288.7s
				13957.4s	66400	179905	9877.2s
26	-116	471520	1040961				
27	-116 -121	610170	1344904	62226.7s	80786	220300	43099.3s
-			1344904			220300	
27		610170	1344904 12409610	62226.7s	80786	220300	43099.3s
27 Total	-121	610170	1344904 12409610 Linear H	62226.7s 375954.0s	80786	220300 2818702	43099.3s
27 Total		610170 5497189	1344904 12409610 Linear H M <sub>sun</sub>	62226.7s 375954.0s Property	80786 1008305	220300 2818702 M <sub>sim</sub>	43099.3s 287617.3s
27 Total Round	-121 log <sub>2</sub> Cor <sub>opt</sub>	610170 5497189 Var	1344904 12409610 Linear H M <sub>sun</sub> Cnf	62226.7s 375954.0s Property T <sup>sol</sup>	80786 1008305 Var	$\frac{220300}{2818702} \\ \frac{M_{sim}}{Cnf}$	$\frac{43099.3s}{287617.3s}$
27 Total Round 1	-121 log <sub>2</sub> Cor <sub>opt</sub>	610170 5497189 Var 223	$\begin{array}{c} 1344904 \\ 12409610 \\ \hline \\ \textbf{Linear I} \\ \hline \\ M_{sun} \\ \hline \\ Cnf \\ 935 \\ \end{array}$	62226.7s 375954.0s <b>Property</b> T <sup>sol</sup> 0.1s	80786 1008305 Var 223	$\frac{220300}{2818702} \\ \frac{M_{sim}}{Cnf} \\ 904$	$   \begin{array}{r}     43099.3s \\     287617.3s \\     \hline     T^{sol} \\     0.1s \\   \end{array} $
$\frac{27}{\text{Total}}$ Round $\frac{1}{2}$	-121 log <sub>2</sub> Cor <sub>opt</sub>	610170 5497189 Var 223 382	$\begin{array}{c} 1344904 \\ 12409610 \\ \hline \\ \textbf{Linear I} \\ \hline \\ M_{sun} \\ \hline \\ Cnf \\ 935 \\ 1900 \\ \end{array}$	$\begin{array}{c} 62226.7 \text{s} \\ 375954.0 \text{s} \\ \hline \\ \textbf{Property} \\ \hline \\ T^{sol} \\ 0.1 \text{s} \\ 0.2 \text{s} \end{array}$	80786 1008305 Var 223 382	$\frac{220300}{2818702} \\ \frac{M_{sim}}{Cnf} \\ \frac{904}{1807}$	$\begin{array}{c} 43099.3 \text{s} \\ 287617.3 \text{s} \\ \hline \\ T^{sol} \\ 0.1 \text{s} \\ 0.2 \text{s} \end{array}$
$     \begin{array}{r}       27 \\       Total     \end{array}     $ Round $     \begin{array}{r}       1 \\       2 \\       3     \end{array}   $	-121 log <sub>2</sub> Cor <sub>opt</sub> 0 0 -1	610170 5497189 Var 223 382 1174	$\frac{1344904}{12409610} \\ \textbf{Linear I} \\ \frac{M_{sun}}{Cnf} \\ 935 \\ 1900 \\ 5879 \\ \end{array}$	$\begin{array}{c} 62226.7 \text{s} \\ 375954.0 \text{s} \\ \textbf{Property} \\ \hline \\ T^{sol} \\ 0.1 \text{s} \\ 0.2 \text{s} \\ 0.3 \text{s} \\ \end{array}$	80786 1008305 Var 223 382 1174	$\frac{220300}{2818702}$ $\frac{M_{sim}}{Cnf}$ 904 1807 5602	$\begin{array}{c} 43099.3 \text{s} \\ 287617.3 \text{s} \\ \hline \\ 0.1 \text{s} \\ 0.2 \text{s} \\ 0.2 \text{s} \\ 0.2 \text{s} \end{array}$
$   \begin{array}{r}     27 \\     Total   \end{array} $ Round $   \begin{array}{r}     1 \\     2 \\     3 \\     4   \end{array} $	-121 log <sub>2</sub> Cor <sub>opt</sub> 0 -1 -3	610170 5497189 Var 223 382 1174 2838	$\begin{array}{c} 1344904\\ 12409610\\ \hline \\ \textbf{Linear H}\\ \hline \\ M_{sun}\\ \hline \\ Cnf\\ 935\\ 1900\\ 5879\\ 12856\\ \end{array}$	$\begin{array}{c} 62226.7\mathrm{s}\\ 375954.0\mathrm{s}\\ \mathbf{Property}\\ \hline \\ T^{sol}\\ 0.1\mathrm{s}\\ 0.2\mathrm{s}\\ 0.3\mathrm{s}\\ 0.4\mathrm{s}\\ \end{array}$	80786 1008305 Var 223 382 1174 2650	$\begin{array}{c} 220300\\ 2818702\\ \hline\\ M_{sim}\\ Cnf\\ 904\\ 1807\\ 5602\\ 11927\\ \end{array}$	$\begin{array}{c} 43099.3 \text{s} \\ 287617.3 \text{s} \\ \hline \\ \hline \\ 0.1 \text{s} \\ 0.2 \text{s} \\ 0.2 \text{s} \\ 0.3 \text{s} \\ \end{array}$
27 Total Round 1 2 3 4 5	-121 $\log_2 Cor_{opt}$ 0 -1 -3 -6	610170 5497189 Var 223 382 1174 2838 6208	$\begin{array}{c} 1344904\\ 12409610\\ \hline \textbf{Linear I}\\ \hline M_{sun}\\ \hline Cnf\\ 935\\ 1900\\ 5879\\ 12856\\ 24811\\ \end{array}$	$\begin{array}{c} 62226.7\mathrm{s}\\ 375954.0\mathrm{s}\\ \mathbf{Property}\\ \hline \\ \hline \\ T^{sol}\\ 0.1\mathrm{s}\\ 0.2\mathrm{s}\\ 0.3\mathrm{s}\\ 0.4\mathrm{s}\\ 1.4\mathrm{s}\\ \end{array}$	80786 1008305 Var 223 382 1174 2650 5200	$\begin{array}{c} 220300\\ 2818702\\ \hline\\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ $	$\begin{array}{c} 43099.3\mathrm{s}\\ 287617.3\mathrm{s}\\ \hline \\ 0.1\mathrm{s}\\ 0.2\mathrm{s}\\ 0.2\mathrm{s}\\ 0.3\mathrm{s}\\ 1.0\mathrm{s}\\ \end{array}$
27 Total Round 1 2 3 4 5 6	-121 log <sub>2</sub> Cor <sub>opt</sub> 0 -1 -3 -6 -9	610170 5497189 Var 223 382 1174 2838 6208 9622	$\begin{array}{c} 1344904\\ 12409610\\ \hline \textbf{Linear I}\\ \hline M_{sun}\\ \hline Cnf\\ 935\\ 1900\\ 5879\\ 12856\\ 24811\\ 34583\\ \end{array}$	$\begin{array}{c} 62226.7\mathrm{s}\\ 375954.0\mathrm{s}\\ \mathbf{Property}\\ \hline \\ \hline \\ 0.1\mathrm{s}\\ 0.2\mathrm{s}\\ 0.3\mathrm{s}\\ 0.4\mathrm{s}\\ 1.4\mathrm{s}\\ 3.9\mathrm{s}\\ \end{array}$	80786 1008305 Var 223 382 1174 2650 5200 7102	$\begin{array}{c} 220300\\ 2818702\\ \hline\\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ $	$\begin{array}{c} 43099.3\mathrm{s}\\ 287617.3\mathrm{s}\\ \hline \\ 0.1\mathrm{s}\\ 0.2\mathrm{s}\\ 0.2\mathrm{s}\\ 0.3\mathrm{s}\\ 1.0\mathrm{s}\\ 3.2\mathrm{s}\\ \end{array}$
27 Total Round 1 2 3 4 5 6 7	-121 log <sub>2</sub> Cor <sub>opt</sub> 0 -1 -3 -6 -9 -13	610170 5497189 Var 223 382 1174 2838 6208 9622 17765	$\begin{array}{c} 1344904\\ 12409610\\ \hline \\ \textbf{Linear I}\\ \hline \\ M_{sun}\\ \hline \\ Cnf\\ 935\\ 1900\\ 5879\\ 12856\\ 24811\\ 34583\\ 58536\\ \end{array}$	$\begin{array}{c} 62226.7\mathrm{s}\\ 375954.0\mathrm{s}\\ \mathbf{Property}\\ \hline \\ \hline \\ 0.1\mathrm{s}\\ 0.2\mathrm{s}\\ 0.3\mathrm{s}\\ 0.4\mathrm{s}\\ 1.4\mathrm{s}\\ 3.9\mathrm{s}\\ 55.2\mathrm{s}\\ \end{array}$	80786 1008305 223 382 1174 2650 5200 7102 11785	$\begin{array}{c} 220300\\ 2818702\\ \\ \hline \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\$	$\begin{array}{c} 43099.3 {\rm s}\\ 287617.3 {\rm s}\\ \hline \\ 0.1 {\rm s}\\ 0.2 {\rm s}\\ 0.2 {\rm s}\\ 0.3 {\rm s}\\ 1.0 {\rm s}\\ 3.2 {\rm s}\\ 40.1 {\rm s}\\ \end{array}$
27 Total Round 1 2 3 4 5 6 7 8	-121 log <sub>2</sub> Cor <sub>opt</sub> 0 -1 -3 -6 -9 -13 -17	$\begin{array}{c} 610170\\ 5497189\\ \hline\\ Var\\ 223\\ 382\\ 1174\\ 2838\\ 6208\\ 9622\\ 17765\\ 25205\\ \end{array}$	$\begin{array}{c} 1344904\\ 12409610\\ \hline \\ \textbf{Linear I}\\ \hline \\ M_{sun}\\ Cnf\\ 935\\ 1900\\ 5879\\ 12856\\ 24811\\ 34583\\ 58536\\ 77401\\ \end{array}$	$\begin{array}{c} 62226.7\mathrm{s}\\ 375954.0\mathrm{s}\\ \mathbf{Property}\\ \hline \\ \hline \\ 0.1\mathrm{s}\\ 0.2\mathrm{s}\\ 0.3\mathrm{s}\\ 0.4\mathrm{s}\\ 1.4\mathrm{s}\\ 3.9\mathrm{s}\\ 55.2\mathrm{s}\\ 452.1\mathrm{s}\\ \end{array}$	$\begin{array}{c} 80786\\ 1008305\\ \hline\\ \hline\\ Var\\ 223\\ 382\\ 1174\\ 2650\\ 5200\\ 7102\\ 11785\\ 15135\\ \end{array}$	$\begin{array}{c} 220300\\ 2818702\\ \hline\\ M_{sim}\\ \hline\\ Cnf\\ 904\\ 1807\\ \hline\\ 5602\\ 11927\\ 21556\\ 27676\\ 43300\\ \hline\\ 52885\\ \end{array}$	$\begin{array}{c} 43099.3\mathrm{s}\\ 287617.3\mathrm{s}\\ \hline \\ 287617.3\mathrm{s}\\ 0.1\mathrm{s}\\ 0.2\mathrm{s}\\ 0.2\mathrm{s}\\ 0.2\mathrm{s}\\ 0.3\mathrm{s}\\ 1.0\mathrm{s}\\ 3.2\mathrm{s}\\ 40.1\mathrm{s}\\ 440.0\mathrm{s}\\ \end{array}$
$\begin{array}{c} 27\\ Total\\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ $	-121 log <sub>2</sub> Cor <sub>opt</sub> 0 -1 -3 -6 -9 -13 -17 -19	610170 5497189 Var 223 382 1174 2838 6208 9622 9765 17765 25205 19497	$\begin{array}{c} 1344904\\ 12409610\\ \hline \\ \textbf{Linear H}\\ \hline \\ M_{sun}\\ \hline \\ Cnf\\ 935\\ 1900\\ 5879\\ 12856\\ 24811\\ 34583\\ 58536\\ 77401\\ 57676\\ \end{array}$	$\begin{array}{c} 62226.7\mathrm{s}\\ 375954.0\mathrm{s}\\ \mathbf{Property}\\ \hline \\ \hline \\ \hline \\ 0.1\mathrm{s}\\ 0.2\mathrm{s}\\ 0.4\mathrm{s}\\ 1.4\mathrm{s}\\ 3.9\mathrm{s}\\ 55.2\mathrm{s}\\ 452.1\mathrm{s}\\ 787.2\mathrm{s}\\ \end{array}$	80786 1008305 Var 223 382 1174 2650 5200 7102 11785 15135 10267	$\begin{array}{c} 220300\\ 2818702\\ \hline\\ M_{sim}\\ Cnf\\ 904\\ 1807\\ 5602\\ 11927\\ 21556\\ 27676\\ 43300\\ 52885\\ 35840\\ \end{array}$	$\begin{array}{c} 43099.3\mathrm{s}\\ 287617.3\mathrm{s}\\ \hline \\ 287617.3\mathrm{s}\\ \hline \\ 0.1\mathrm{s}\\ 0.2\mathrm{s}\\ 0.2\mathrm{s}\\ 0.3\mathrm{s}\\ 1.0\mathrm{s}\\ 3.2\mathrm{s}\\ 40.1\mathrm{s}\\ 440.0\mathrm{s}\\ 417.7\mathrm{s}\\ \end{array}$
$     \begin{array}{r}       27 \\       Total \\       1 \\       2 \\       3 \\       4 \\       5 \\       6 \\       7 \\       8 \\       9 \\       10 \\     \end{array} $	$\begin{array}{c} -121 \\ \\ \\ 0 \\ 0 \\ -1 \\ -3 \\ -6 \\ -9 \\ -13 \\ -17 \\ -19 \\ -21 \\ \end{array}$	610170 5497189 Var 223 382 1174 2838 6208 9622 17765 25205 19497 23502	$\begin{array}{c} 1344904\\ 12409610\\ \hline \\ \textbf{Linear I}\\ \hline \\ M_{sun}\\ Cnf\\ 935\\ 1900\\ 5879\\ 12856\\ 24811\\ 34583\\ 58536\\ 77401\\ 57676\\ 68269\\ \end{array}$	$\begin{array}{c} 62226.7\mathrm{s}\\ 375954.0\mathrm{s}\\ \end{array}$ Property $\begin{array}{c} T^{sol}\\ 0.1\mathrm{s}\\ 0.2\mathrm{s}\\ 0.3\mathrm{s}\\ 0.4\mathrm{s}\\ 1.4\mathrm{s}\\ 3.9\mathrm{s}\\ 55.2\mathrm{s}\\ 452.1\mathrm{s}\\ 787.2\mathrm{s}\\ 161.9\mathrm{s}\\ \end{array}$	80786 1008305 Var 223 382 1174 2650 5200 7102 11785 15135 10267 10232	$\begin{array}{c} 220300\\ 2818702\\ \hline\\ M_{sim}\\ Cnf\\ 904\\ 1807\\ 5602\\ 11927\\ 21556\\ 27676\\ 43300\\ 52885\\ 35840\\ 35513\\ \end{array}$	$\begin{array}{c} 43099.3 {\rm s}\\ 287617.3 {\rm s}\\ 287617.3 {\rm s}\\ 0.1 {\rm s}\\ 0.2 {\rm s}\\ 0.2 {\rm s}\\ 0.2 {\rm s}\\ 0.3 {\rm s}\\ 1.0 {\rm s}\\ 3.2 {\rm s}\\ 40.1 {\rm s}\\ 440.0 {\rm s}\\ 4417.7 {\rm s}\\ 231.5 {\rm s}\\ \end{array}$
$\begin{array}{c} 27 \\ Total \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\$	-121 log <sub>2</sub> Cor <sub>opt</sub> 0 -1 -3 -6 -9 -13 -17 -19 -21 -24	610170 5497189 Var 223 382 1174 2838 6208 9622 17765 2505 19497 23502 37852	$\begin{array}{c} 1344904\\ 12409610\\ \hline \\ \textbf{Linear H}\\ \hline \\ M_{sun}\\ Cnf\\ 935\\ 1900\\ 5879\\ 12856\\ 24811\\ 34583\\ 58536\\ 77401\\ 57676\\ 668269\\ 107623\\ \end{array}$	$\begin{array}{c} 62226.7 \text{s}\\ 375954.0 \text{s}\\ \hline \textbf{T}^{sol}\\ 0.1 \text{s}\\ 0.2 \text{s}\\ 0.3 \text{s}\\ 0.4 \text{s}\\ 1.4 \text{s}\\ 3.9 \text{s}\\ 55.2 \text{s}\\ 452.1 \text{s}\\ 787.2 \text{s}\\ 161.9 \text{s}\\ 570.3 \text{s}\\ \end{array}$	80786 1008305 Var 223 382 1174 2650 5200 7102 11785 15135 10267 10732 15604	$\begin{array}{c} 220300\\ 2818702\\ \hline\\ \\ \hline\\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\$	$\begin{array}{c} 43099.3 {\rm s}\\ 287617.3 {\rm s}\\ 287617.3 {\rm s}\\ 287617.3 {\rm s}\\ 287617.3 {\rm s}\\ 0.1 {\rm s}\\ 0.2 {\rm s}\\ 0.2 {\rm s}\\ 0.3 {\rm s}\\ 1.0 {\rm s}\\ 3.2 {\rm s}\\ 40.1 {\rm s}\\ 440.0 {\rm s}\\ 440.0 {\rm s}\\ 417.7 {\rm s}\\ 231.5 {\rm s}\\ 377.1 {\rm s}\\ \end{array}$
$\begin{array}{c} 27 \\ Total \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\$	-121 log <sub>2</sub> Cor <sub>opt</sub> 0 0 -1 -3 -6 -9 -13 -17 -19 -21 -24 -27	610170 5497189 223 382 1174 2838 6208 9622 17765 25205 19497 23502 37852 45730	$\begin{array}{c} 1344904\\ 12409610\\ \hline \\ \textbf{Linear H}\\ \hline \\ M_{sun}\\ Cnf\\ 935\\ 1900\\ 5879\\ 12856\\ 24811\\ 34583\\ 58536\\ 77401\\ 57676\\ 68269\\ 107623\\ 127067\\ \end{array}$	$\begin{array}{c} 62226.7 \mathrm{s} \\ 375954.0 \mathrm{s} \\ \end{array}$ Property $\begin{array}{c} T^{sol} \\ 0.1 \mathrm{s} \\ 0.2 \mathrm{s} \\ 0.3 \mathrm{s} \\ 0.4 \mathrm{s} \\ 1.4 \mathrm{s} \\ 3.9 \mathrm{s} \\ 55.2 \mathrm{s} \\ 452.1 \mathrm{s} \\ 787.2 \mathrm{s} \\ 161.9 \mathrm{s} \\ 570.3 \mathrm{s} \\ 742.3 \mathrm{s} \end{array}$	80786 1008305 223 382 1174 2650 5200 7102 11785 15135 10267 10732 15604 17506	$\begin{array}{c} 220300\\ 2818702\\ \hline\\ M_{sim}\\ Cnf\\ 904\\ 1807\\ 5602\\ 11927\\ 21556\\ 27676\\ 43300\\ 52885\\ 35840\\ 38513\\ 88513\\ 38513\\ 856260\\ 62380\\ \end{array}$	$\begin{array}{c} 43099.3\mathrm{s}\\ 287617.3\mathrm{s}\\ 287617.3\mathrm{s}\\ 287617.3\mathrm{s}\\ 287617.3\mathrm{s}\\ 0.1\mathrm{s}\\ 0.2\mathrm{s}\\ 0.2\mathrm{s}\\ 0.2\mathrm{s}\\ 0.3\mathrm{s}\\ 1.0\mathrm{s}\\ 3.2\mathrm{s}\\ 40.1\mathrm{s}\\ 440.0\mathrm{s}\\ 417.7\mathrm{s}\\ 231.5\mathrm{s}\\ 377.1\mathrm{s}\\ 577.2\mathrm{s}\\ \end{array}$
$\begin{array}{c} 27 \\ Total \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\$	-121 log <sub>2</sub> Cor <sub>opt</sub> 0 0 -1 -3 -6 -9 -13 -17 -19 -21 -24 -27 -30	610170 5497189 Var 223 382 1174 2838 6208 9622 17765 25205 19497 23502 37852 45730 54352	$\begin{array}{c} 1344904\\ 12409610\\ \hline \\ \textbf{Linear I}\\ \hline \\ M_{sun}\\ \hline \\ Cnf\\ 935\\ 1900\\ 5879\\ 12856\\ 24811\\ 34583\\ 58536\\ 77401\\ 57676\\ 68269\\ 107623\\ 127067\\ 148123\\ \end{array}$	$\begin{array}{c} 62226.7\mathrm{s}\\ 375954.0\mathrm{s}\\ \mathbf{Property}\\ \hline \\ \hline \\ \hline \\ 0.1\mathrm{s}\\ 0.2\mathrm{s}\\ 0.3\mathrm{s}\\ 0.4\mathrm{s}\\ 1.4\mathrm{s}\\ 3.9\mathrm{s}\\ 55.2\mathrm{s}\\ 452.1\mathrm{s}\\ 787.2\mathrm{s}\\ 161.9\mathrm{s}\\ 570.3\mathrm{s}\\ 742.3\mathrm{s}\\ 2064.8\mathrm{s}\\ \end{array}$	80786 1008305 223 382 1174 2650 5200 7102 11785 15135 10267 10732 15604 17506 19408	$\begin{array}{c} 220300\\ 2818702\\ \hline\\ M_{sim}\\ \hline\\ Cnf\\ 904\\ 1807\\ 5602\\ 11927\\ 21556\\ 27676\\ 43300\\ 52885\\ 35840\\ 38513\\ 56260\\ 62380\\ 62380\\ 68500\\ \end{array}$	$\begin{array}{c} 43099.3\mathrm{s}\\ 287617.3\mathrm{s}\\ 287617.3\mathrm{s}\\ 287617.3\mathrm{s}\\ 287617.3\mathrm{s}\\ 0.1\mathrm{s}\\ 0.2\mathrm{s}\\ 0.2\mathrm{s}\\ 0.2\mathrm{s}\\ 0.3\mathrm{s}\\ 1.0\mathrm{s}\\ 3.2\mathrm{s}\\ 40.1\mathrm{s}\\ 440.0\mathrm{s}\\ 4417.7\mathrm{s}\\ 2317.5\mathrm{s}\\ 3377.1\mathrm{s}\\ 577.2\mathrm{s}\\ 1918.9\mathrm{s}\\ \end{array}$
27 Total Round 1 2 3 4 5 6 6 7 8 9 10 11 12 13 14	-121 log <sub>2</sub> Cor <sub>opt</sub> 0 0 -1 -3 -6 -9 -13 -17 -19 -21 -24 -27 -30 -33	610170 5497189 Var 223 382 1174 2838 6208 9622 17765 25205 19497 23502 37852 45730 54352 63718	$\begin{array}{c} 1344904\\ 12409610\\ \hline \\ \textbf{Linear I}\\ \hline \\ M_{sun}\\ \hline \\ Cnf\\ 935\\ 1900\\ 5879\\ 12856\\ 24811\\ 34583\\ 58536\\ 77401\\ 57676\\ 68269\\ 107623\\ 127067\\ 148123\\ 170791\\ \end{array}$	$\begin{array}{r} 62226.7\mathrm{s}\\ 375954.0\mathrm{s}\\ \mathbf{Property}\\ \hline \\ \hline \\ \mathbf{Property}\\ \hline \\ 0.1\mathrm{s}\\ 0.2\mathrm{s}\\ 0.3\mathrm{s}\\ 0.4\mathrm{s}\\ 1.4\mathrm{s}\\ 3.9\mathrm{s}\\ 55.2\mathrm{s}\\ 452.1\mathrm{s}\\ 787.2\mathrm{s}\\ 161.9\mathrm{s}\\ 570.3\mathrm{s}\\ 2064.8\mathrm{s}\\ 2508.2\mathrm{s}\\ \end{array}$	80786 1008305 223 382 1174 2650 5200 11785 15135 10267 10732 15604 17506 19408 21310	$\begin{array}{c} 220300\\ 2818702\\ \hline\\ M_{sim}\\ Cnf\\ 904\\ 1807\\ 5602\\ 11927\\ 21556\\ 27676\\ 43300\\ 52885\\ 35840\\ 38513\\ 56260\\ 62380\\ 68500\\ 74620\\ \end{array}$	$\begin{array}{r} 43099.3\mathrm{s}\\ 287617.3\mathrm{s}\\ 287617.3\mathrm{s}\\ 287617.3\mathrm{s}\\ 287617.3\mathrm{s}\\ 0.1\mathrm{s}\\ 0.2\mathrm{s}\\ 0.2\mathrm{s}\\ 0.2\mathrm{s}\\ 0.2\mathrm{s}\\ 1.0\mathrm{s}\\ 3.2\mathrm{s}\\ 40.1\mathrm{s}\\ 440.0\mathrm{s}\\ 417.7\mathrm{s}\\ 231.5\mathrm{s}\\ 377.1\mathrm{s}\\ 377.1\mathrm{s}\\ 577.2\mathrm{s}\\ 1918.9\mathrm{s}\\ 2327.5\mathrm{s}\\ 2327.5\mathrm{s}\\ \end{array}$
$\begin{array}{c} 27 \\ Total \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\$	$\begin{array}{c} -121\\$	610170 5497189 Var 223 382 1174 2838 6208 9622 17765 2505 2505 2505 37852 19497 23502 37852 45730 54352 63718 93445	$\begin{array}{c} 1344904\\ 12409610\\ \hline \\ \textbf{Linear I}\\ \hline \\ M_{sun}\\ Cnf\\ 935\\ 1900\\ 5879\\ 12856\\ 24811\\ 34583\\ 58536\\ 77401\\ 57676\\ 68269\\ 107623\\ 127067\\ 148123\\ 170791\\ 246156\\ \end{array}$	$\begin{array}{c} 62226.7\mathrm{s}\\ 375954.0\mathrm{s}\\ \mathbf{75954.0\mathrm{s}}\\ \mathbf{Property}\\ \hline \\ \hline \\ 10.1\mathrm{s}\\ 0.2\mathrm{s}\\ 0.3\mathrm{s}\\ 0.4\mathrm{s}\\ 1.4\mathrm{s}\\ 3.9\mathrm{s}\\ 55.2\mathrm{s}\\ 452.1\mathrm{s}\\ 787.2\mathrm{s}\\ 161.9\mathrm{s}\\ 570.3\mathrm{s}\\ 742.3\mathrm{s}\\ 2064.8\mathrm{s}\\ 2508.2\mathrm{s}\\ 58259.1\mathrm{s}\\ \end{array}$	80786 1008305 Var 223 382 1174 2650 5200 7102 11785 15135 10267 10732 15604 17506 19408 21310 30165	$\begin{array}{c} 220300\\ 2818702\\ \hline\\ M_{sim}\\ Cnf\\ 904\\ 1807\\ 5602\\ 11927\\ 21556\\ 27676\\ 43300\\ 52885\\ 35840\\ 38513\\ 56260\\ 62380\\ 68500\\ 74620\\ 103220\\ \end{array}$	$\begin{array}{r} 43099.3\mathrm{s}\\ 287617.3\mathrm{s}\\ 287617.3\mathrm{s}\\ 287617.3\mathrm{s}\\ 287617.3\mathrm{s}\\ 0.1\mathrm{s}\\ 0.2\mathrm{s}\\ 0.2\mathrm{s}\\ 0.2\mathrm{s}\\ 0.3\mathrm{s}\\ 1.0\mathrm{s}\\ 3.2\mathrm{s}\\ 40.1\mathrm{s}\\ 40.0\mathrm{s}\\ 440.0\mathrm{s}\\ 440.0\mathrm{s}\\ 440.0\mathrm{s}\\ 4417.7\mathrm{s}\\ 231.5\mathrm{s}\\ 377.1\mathrm{s}\\ 577.2\mathrm{s}\\ 1918.9\mathrm{s}\\ 2327.5\mathrm{s}\\ 23275.5\mathrm{s}\\ 23275.5\mathrm{s}\\ \end{array}$
$\begin{array}{r} 27\\ Total\\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ $	$\begin{array}{c} -121\\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\$	610170 5497189 Var 223 382 1174 2838 6208 9622 17765 2505 19497 23502 37852 45730 54352 63718 93445 109565	$\begin{array}{c} 1344904\\ 12409610\\ \hline \\ \textbf{Linear I}\\ \hline \\ M_{sun}\\ Cnf\\ 935\\ 1900\\ 5879\\ 12856\\ 24811\\ 34583\\ 58536\\ 77401\\ 57676\\ 68269\\ 107623\\ 127067\\ 148123\\ 170791\\ 246156\\ 283621\\ \end{array}$	$\begin{array}{c} 62226.7\mathrm{s}\\ 375954.0\mathrm{s}\\ 75954.0\mathrm{s}\\ \mathbf{Property}\\ \hline \\ \hline \\ 0.1\mathrm{s}\\ 0.2\mathrm{s}\\ 0.3\mathrm{s}\\ 0.4\mathrm{s}\\ 1.4\mathrm{s}\\ 3.9\mathrm{s}\\ 55.2\mathrm{s}\\ 452.1\mathrm{s}\\ 787.2\mathrm{s}\\ 161.9\mathrm{s}\\ 570.3\mathrm{s}\\ 742.3\mathrm{s}\\ 2604.8\mathrm{s}\\ 2508.2\mathrm{s}\\ 58259.1\mathrm{s}\\ 246564.5\mathrm{s}\\ \end{array}$	80786 1008305 Var 223 382 1174 2650 5200 7102 11785 15135 10267 10267 10267 10267 10267 10732 15604 17506 19408 21310 30165 34755	$\begin{array}{c} 220300\\ 2818702\\ \hline\\ \\ \hline\\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\$	$\begin{array}{r} 43099.3\mathrm{s}\\ 287617.3\mathrm{s}\\ 287617.3\mathrm{s}\\ 287617.3\mathrm{s}\\ 287617.3\mathrm{s}\\ 287617.3\mathrm{s}\\ 0.1\mathrm{s}\\ 0.2\mathrm{s}\\ 0.2\mathrm{s}\\ 0.3\mathrm{s}\\ 1.0\mathrm{s}\\ 3.2\mathrm{s}\\ 40.1\mathrm{s}\\ 440.0\mathrm{s}\\ 440.0\mathrm{s}\\ 440.0\mathrm{s}\\ 440.0\mathrm{s}\\ 4417.7\mathrm{s}\\ 231.5\mathrm{s}\\ 377.1\mathrm{s}\\ 577.2\mathrm{s}\\ 1918.9\mathrm{s}\\ 2327.5\mathrm{s}\\ 23275.5\mathrm{s}\\ 168923.4\mathrm{s}\\ 48923.4\mathrm{s}\\ 4892.4\mathrm{s}\\ 4892.4\mathrm{s}\\$
$\begin{array}{r} 27\\ Total\\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ $	$\begin{array}{c} -121\\ \\ \hline \\ 0\\ 0\\ -1\\ -3\\ -6\\ -9\\ -13\\ -17\\ -19\\ -21\\ -24\\ -27\\ -30\\ -33\\ -37\\ -41\\ -43\\ \end{array}$	610170 5497189 Var 223 382 1174 2838 6208 9622 17765 25205 19497 23502 37852 45730 54352 63718 93445 109565 74577	$\begin{array}{c} 1344904\\ 12409610\\ \hline \\ \textbf{Linear H}\\ \hline \\ M_{sun}\\ \hline \\ Cnf\\ 935\\ 1900\\ 5879\\ 12856\\ 24811\\ 34583\\ 58536\\ 77401\\ 57656\\ 68269\\ 107623\\ 127067\\ 148123\\ 170791\\ 246156\\ 283621\\ 191080\\ \end{array}$	$\begin{array}{c} 62226.7\mathrm{s}\\ 375954.0\mathrm{s}\\ 75954.0\mathrm{s}\\ \mathbf{Property}\\ \hline \\ \hline \\ 0.1\mathrm{s}\\ 0.2\mathrm{s}\\ 0.3\mathrm{s}\\ 0.4\mathrm{s}\\ 1.4\mathrm{s}\\ 3.9\mathrm{s}\\ 55.2\mathrm{s}\\ 452.1\mathrm{s}\\ 452.1\mathrm{s}\\ 452.1\mathrm{s}\\ 452.1\mathrm{s}\\ 787.2\mathrm{s}\\ 161.9\mathrm{s}\\ 570.3\mathrm{s}\\ 742.3\mathrm{s}\\ 2064.8\mathrm{s}\\ 2508.2\mathrm{s}\\ 246564.5\mathrm{s}\\ 15661.2\mathrm{s}\\ 15661.2\mathrm{s}\\ \end{array}$	80786 1008305 223 382 1174 2650 7102 11785 15135 10267 10732 15604 17506 19408 21310 30165 34755 22039	$\begin{array}{c} 220300\\ 2818702\\ \hline\\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ $	$\begin{array}{r} 43099.3\mathrm{s}\\ 287617.3\mathrm{s}\\ 287617.3\mathrm{s}\\ 287617.3\mathrm{s}\\ 287617.3\mathrm{s}\\ 287617.3\mathrm{s}\\ 0.2\mathrm{s}\\ 0.2\mathrm{s}\\ 0.2\mathrm{s}\\ 0.3\mathrm{s}\\ 1.0\mathrm{s}\\ 3.2\mathrm{s}\\ 40.1\mathrm{s}\\ 440.0\mathrm{s}\\ 440.0\mathrm{s}\\ 440.0\mathrm{s}\\ 440.0\mathrm{s}\\ 440.0\mathrm{s}\\ 440.0\mathrm{s}\\ 3.2\mathrm{s}\\ 440.0\mathrm{s}\\ 3.2\mathrm{s}\\ 40.1\mathrm{s}\\ 577.2\mathrm{s}\\ 1918.9\mathrm{s}\\ 2327.5\mathrm{s}\\ 1918.9\mathrm{s}\\ 2327.5\mathrm{s}\\ 12327.5\mathrm{s}\\ 168923.4\mathrm{s}\\ 12542.8\mathrm{s}\\ 12542.8\mathrm{s}$
$\begin{array}{c} 27 \\ Total \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\$	$\begin{array}{c} -121\\ \\ \hline \\ 0\\ 0\\ -1\\ -3\\ -6\\ -9\\ -13\\ -17\\ -19\\ -21\\ -24\\ -27\\ -30\\ -33\\ -37\\ -41\\ -43\\ -45\\ \end{array}$	610170 5497189 Var 223 382 1174 2838 6208 9622 17765 25205 19497 23502 23502 37852 37852 45730 54352 63718 93445 109565 74577 82302	$\begin{array}{c} 1344904\\ 12409610\\ \hline 12409610\\ \hline Linear I \\ \hline M_{sun} \\ Cnf\\ 935\\ 1900\\ 5879\\ 12856\\ 24811\\ 34583\\ 58536\\ 77401\\ 57676\\ 68269\\ 107623\\ 127067\\ 148123\\ 170791\\ 246156\\ 283621\\ 191080\\ 209857\\ \end{array}$	$\begin{array}{c} 62226.7\mathrm{s}\\ 375954.0\mathrm{s}\\ 75954.0\mathrm{s}\\ \mathbf{Property}\\ \hline \\ \hline \\ 0.1\mathrm{s}\\ 0.2\mathrm{s}\\ 0.3\mathrm{s}\\ 0.4\mathrm{s}\\ 1.4\mathrm{s}\\ 3.9\mathrm{s}\\ 55.2\mathrm{s}\\ 452.1\mathrm{s}\\ 787.2\mathrm{s}\\ 161.9\mathrm{s}\\ 570.3\mathrm{s}\\ 742.3\mathrm{s}\\ 2064.8\mathrm{s}\\ 2508.2\mathrm{s}\\ 58259.1\mathrm{s}\\ 246564.5\mathrm{s}\\ 15661.2\mathrm{s}\\ 2447.7\mathrm{s}\\ \end{array}$	80786 1008305 223 382 1174 2650 5200 7102 11785 15135 10267 10732 15604 17506 19408 21310 30165 34755 22039 21760	$\begin{array}{c} 220300\\ 2818702\\ \hline\\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ $	$\begin{array}{r} 43099.3\mathrm{s}\\ 287617.3\mathrm{s}\\ 287617.3\mathrm{s}\\ 287617.3\mathrm{s}\\ 287617.3\mathrm{s}\\ 0.2\mathrm{s}\\ 0.2\mathrm{s}\\ 0.2\mathrm{s}\\ 0.2\mathrm{s}\\ 0.3\mathrm{s}\\ 1.0\mathrm{s}\\ 3.2\mathrm{s}\\ 40.1\mathrm{s}\\ 440.0\mathrm{s}\\ 417.7\mathrm{s}\\ 231.5\mathrm{s}\\ 317.1\mathrm{s}\\ 577.2\mathrm{s}\\ 1918.9\mathrm{s}\\ 2327.5\mathrm{s}\\ 23275.5\mathrm{s}\\ 23275.5\mathrm{s}\\ 23275.5\mathrm{s}\\ 12542.8\mathrm{s}\\ 12542.8\mathrm{s}\\ 1987.3\mathrm{s}\\ \end{array}$
$\begin{array}{r} 27\\ Total\\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ $	$\begin{array}{c} -121\\$	610170 5497189 Var 223 382 1174 2838 6208 9622 17765 25205 19497 23502 37852 45730 54352 63718 93445 109565 74577 82302 90399	$\begin{array}{c} 1344904\\ 12409610\\ \hline 12409610\\ \hline Linear I \\ M_{sun}\\ Cnf\\ 935\\ 1900\\ 5879\\ 12856\\ 24811\\ 34583\\ 58536\\ 77401\\ 57676\\ 68269\\ 107623\\ 127067\\ 148123\\ 170791\\ 246156\\ 283621\\ 191080\\ 209857\\ 229471\\ \end{array}$	$\begin{array}{r} 62226.7s\\ 375954.0s\\ \hline roperty\\ \hline T^{sol}\\ 0.1s\\ 0.2s\\ 0.3s\\ 0.4s\\ 1.4s\\ 3.9s\\ 55.2s\\ 452.1s\\ 787.2s\\ 161.9s\\ 570.3s\\ 742.3s\\ 2064.8s\\ 2508.2s\\ 58259.1s\\ 246564.5s\\ 2467.7s\\ 2184.9s\\ \end{array}$	80786 1008305 223 382 1174 2650 5200 5200 5200 5102 11785 15135 10267 10732 15604 17506 19408 21310 30165 34755 22039 21760 21760	$\begin{array}{c} 220300\\ 2818702\\ \hline\\ 818702\\ \hline\\ 818702\\ \hline\\ 904\\ \hline\\ 1807\\ \hline\\ 5602\\ \hline\\ 11927\\ \hline\\ 21556\\ \hline\\ 27676\\ \hline\\ 43300\\ \hline\\ 52885\\ \hline\\ 35840\\ \hline\\ 35840\\ \hline\\ 35840\\ \hline\\ 35840\\ \hline\\ 35840\\ \hline\\ 35840\\ \hline\\ 62380\\ \hline\\ 74620\\ \hline\\ 103220\\ \hline\\ 115285\\ \hline\\ 73280\\ \hline\\ 73280\\ \hline\\ 74655\\ \hline\\ 75650\\ \hline\end{array}$	$\begin{array}{r} 43099.3\mathrm{s}\\ 287617.3\mathrm{s}\\ 287617.3\mathrm{s}\\ 287617.3\mathrm{s}\\ 287617.3\mathrm{s}\\ 0.1\mathrm{s}\\ 0.2\mathrm{s}\\ 0.2\mathrm{s}\\ 0.2\mathrm{s}\\ 0.3\mathrm{s}\\ 1.0\mathrm{s}\\ 3.2\mathrm{s}\\ 40.1\mathrm{s}\\ 440.0\mathrm{s}\\ 417.7\mathrm{s}\\ 2317.5\mathrm{s}\\ 2317.5\mathrm{s}\\ 2377.1\mathrm{s}\\ 577.2\mathrm{s}\\ 1918.9\mathrm{s}\\ 2327.5\mathrm{s}\\ 23275.5\mathrm{s}\\ 198923.4\mathrm{s}\\ 12542.4\mathrm{s}\\ 1987.3\mathrm{s}\\ 2085.4\mathrm{s}\\ \end{array}$
$\begin{array}{c} 27 \\ Total \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\$	$\begin{array}{c} -121\\ \\ \hline \\ 0\\ 0\\ -1\\ -3\\ -6\\ -9\\ -13\\ -17\\ -19\\ -21\\ -24\\ -27\\ -30\\ -33\\ -37\\ -41\\ -43\\ -45\\ -47\\ -49\\ \end{array}$	610170 5497189 Var 223 382 1174 2838 6208 9622 17765 2505 2505 37852 45730 54352 45730 54352 63718 93445 109565 74577 82302 90399 98868	$\begin{array}{c} 1344904\\ 12409610\\ \hline \\ 12409610\\ \hline \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\$	$\begin{array}{c} 62226.7 \mathrm{s} \\ 375954.0 \mathrm{s} \\ \hline 75954.0 \mathrm{s} \\ \hline 75954.0 \mathrm{s} \\ \hline 75954.0 \mathrm{s} \\ \hline 750100000000000000000000000000000000000$	80786 1008305 Var 223 382 1174 2650 5200 7102 11785 15135 10267 10732 15604 17506 19408 21310 30165 34755 22039 21760 21481 21202	$\begin{array}{c} 220300\\ 2818702\\ \hline\\ \\ \hline\\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\$	$\begin{array}{r} 43099.3s\\ 287617.3s\\ 287617.3s\\ 287617.3s\\ 287617.3s\\ 0.2s\\ 0.2s\\ 0.2s\\ 0.2s\\ 0.3s\\ 1.0s\\ 3.2s\\ 40.1s\\ 40.0s\\ 417.7s\\ 231.5s\\ 377.1s\\ 577.2s\\ 1918.9s\\ 2327.5s\\ 23275.5s\\ 168923.4s\\ 12542.8s\\ 1987.3s\\ 2085.4s\\ 643.7s\\ \end{array}$
$\begin{array}{r} 27\\ Total\\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ $	$\begin{array}{c} -121\\$	610170 5497189 Var 223 382 1174 2838 6208 9622 17765 2505 2505 2505 2505 2505 37852 45730 54352 63718 93445 109565 74577 82302 90399 98868 144912	$\begin{array}{c} 1344904\\ 12409610\\ \hline 12409610\\ \hline Linear I \\ M_{sun}\\ Cnf\\ 935\\ 1900\\ 5879\\ 12856\\ 24811\\ 34583\\ 58536\\ 77401\\ 57676\\ 68269\\ 107623\\ 127067\\ 148123\\ 170791\\ 246156\\ 283621\\ 191080\\ 209857\\ 229471\\ \end{array}$	$\begin{array}{r} 62226.7\mathrm{s}\\ 375954.0\mathrm{s}\\ 75954.0\mathrm{s}\\ \mathbf{Property}\\ \hline \\ \hline \\ 10.1\mathrm{s}\\ 0.2\mathrm{s}\\ 0.3\mathrm{s}\\ 0.4\mathrm{s}\\ 1.4\mathrm{s}\\ 3.9\mathrm{s}\\ 55.2\mathrm{s}\\ 452.1\mathrm{s}\\ 787.2\mathrm{s}\\ 161.9\mathrm{s}\\ 570.3\mathrm{s}\\ 742.3\mathrm{s}\\ 2508.2\mathrm{s}\\ 58259.1\mathrm{s}\\ 246564.5\mathrm{s}\\ 15661.2\mathrm{s}\\ 2447.7\mathrm{s}\\ 2184.9\mathrm{s}\\ 549.0\mathrm{s}\\ 108.0\mathrm{s}\\ \end{array}$	80786 1008305 Var 223 382 1174 2650 5200 7102 11785 15135 10267 10732 15604 17506 19408 21310 21310 21310 21310 21310 21341 21202 29192	$\begin{array}{c} 220300\\ 2818702\\ \hline\\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ $	$\begin{array}{r} 43099.3\mathrm{s}\\ 287617.3\mathrm{s}\\ 287617.3\mathrm{s}\\ 287617.3\mathrm{s}\\ 287617.3\mathrm{s}\\ 287617.3\mathrm{s}\\ 20100000000000000000000000000000000000$
$\begin{array}{c} 27 \\ Total \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\$	$\begin{array}{c} -121\\ \\ \hline \\ 0\\ 0\\ -1\\ -3\\ -6\\ -9\\ -13\\ -17\\ -19\\ -21\\ -24\\ -27\\ -30\\ -33\\ -37\\ -41\\ -43\\ -45\\ -47\\ -49\\ \end{array}$	610170 5497189 Var 223 382 1174 2838 6208 9622 17765 2505 2505 37852 45730 54352 45730 54352 63718 93445 109565 74577 82302 90399 98868	$\begin{array}{c} 1344904\\ 12409610\\ \hline \\ 12409610\\ \hline \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\$	$\begin{array}{c} 62226.7 \mathrm{s} \\ 375954.0 \mathrm{s} \\ \hline 75954.0 \mathrm{s} \\ \hline 75954.0 \mathrm{s} \\ \hline 75954.0 \mathrm{s} \\ \hline 750100000000000000000000000000000000000$	80786 1008305 Var 223 382 1174 2650 5200 7102 11785 15135 10267 10732 15604 17506 19408 21310 30165 34755 22039 21760 21481 21202	$\begin{array}{c} 220300\\ 2818702\\ \hline\\ \\ \hline\\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\$	$\begin{array}{r} 43099.3s\\ 287617.3s\\ 287617.3s\\ 287617.3s\\ 287617.3s\\ 0.2s\\ 0.2s\\ 0.2s\\ 0.2s\\ 0.3s\\ 1.0s\\ 3.2s\\ 40.1s\\ 40.0s\\ 417.7s\\ 231.5s\\ 377.1s\\ 577.2s\\ 1918.9s\\ 2327.5s\\ 23275.5s\\ 168923.4s\\ 12542.8s\\ 1987.3s\\ 2085.4s\\ 643.7s\\ \end{array}$
$\begin{array}{c} 27 \\ Total \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\$	$\begin{array}{c} -121\\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\$	610170 5497189 Var 223 382 1174 2838 6208 9622 17765 2505 2505 2505 2505 2505 37852 45730 54352 63718 93445 109565 74577 82302 90399 98868 144912	$\begin{array}{c} 1344904\\ 12409610\\ \hline 12409610\\ \hline \\ \textbf{Linear I}\\ \hline \\ \\ \hline \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\$	$\begin{array}{r} 62226.7\mathrm{s}\\ 375954.0\mathrm{s}\\ 75954.0\mathrm{s}\\ \mathbf{Property}\\ \hline \\ \hline \\ 10.1\mathrm{s}\\ 0.2\mathrm{s}\\ 0.3\mathrm{s}\\ 0.4\mathrm{s}\\ 1.4\mathrm{s}\\ 3.9\mathrm{s}\\ 55.2\mathrm{s}\\ 452.1\mathrm{s}\\ 787.2\mathrm{s}\\ 161.9\mathrm{s}\\ 570.3\mathrm{s}\\ 742.3\mathrm{s}\\ 2508.2\mathrm{s}\\ 58259.1\mathrm{s}\\ 246564.5\mathrm{s}\\ 15661.2\mathrm{s}\\ 2447.7\mathrm{s}\\ 2184.9\mathrm{s}\\ 549.0\mathrm{s}\\ 108.0\mathrm{s}\\ \end{array}$	80786 1008305 Var 223 382 1174 2650 5200 7102 11785 15135 10267 10732 15604 17506 19408 21310 21310 21310 21310 21310 21341 21202 29192	$\begin{array}{c} 220300\\ 2818702\\ \hline\\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ $	$\begin{array}{r} 43099.3\mathrm{s}\\ 287617.3\mathrm{s}\\ 287617.3\mathrm{s}\\ 287617.3\mathrm{s}\\ 287617.3\mathrm{s}\\ 287617.3\mathrm{s}\\ 20100000000000000000000000000000000000$
$\begin{array}{c} 27 \\ Total \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\$	$\begin{array}{c} -121\\ \\ \hline \\ 0\\ 0\\ -1\\ -3\\ -6\\ -9\\ -13\\ -17\\ -19\\ -21\\ -24\\ -27\\ -30\\ -33\\ -37\\ -41\\ -43\\ -45\\ -47\\ -49\\ -52\\ -54\\ \end{array}$	610170 5497189 Var 223 382 1174 2838 6208 9622 17765 25205 19497 23502 37852 45730 54352 63718 93445 109565 74577 82302 90399 998868	$\begin{array}{c} 1344904\\ 12409610\\ \hline 12409610\\ \hline 12409610\\ \hline \\ \hline \\ \hline \\ \hline \\ \hline \\ \hline \\ \\ \hline \\ \\ \hline \\$	$\begin{array}{r} 62226.7 \mathrm{s} \\ 375954.0 \mathrm{s} \\ \hline 75954.0 \mathrm{s} \\ \hline 75000000000000000000000000000000000000$	80786 1008305 Var 223 382 1174 2650 7102 11785 15135 10267 10732 15604 17506 19408 21310 30165 34755 22039 21760 21481 21202 29192 22489	$\begin{array}{c} 220300\\ 2818702\\ \hline\\ 818702\\ \hline\\ 904\\ 1807\\ \hline\\ 5602\\ 11927\\ 21556\\ 27676\\ 43300\\ 52885\\ 35840\\ 38513\\ 56260\\ 62380\\ 68500\\ 74620\\ 103220\\ 115285\\ 73280\\ 74465\\ 73280\\ 74465\\ 75635\\ 76835\\ 106612\\ 82889\\ \end{array}$	$\begin{array}{r} 43099.3s\\ 287617.3s\\ 287617.3s\\ \hline \\ 287617.3s\\ \hline \\ 0.1s\\ 0.2s\\ 0.2s\\ 0.2s\\ 0.3s\\ 1.0s\\ 3.2s\\ 40.1s\\ 440.0s\\ 417.7s\\ 231.5s\\ 377.1s\\ 577.2s\\ 1918.9s\\ 2327.5s\\ 168923.4s\\ 12542.8s\\ 12542.8s\\ 1987.3s\\ 2085.4s\\ 643.7s\\ 96.8s\\ 32.2s\\ \end{array}$
27 Total Round 1 2 3 4 5 6 7 8 9 9 10 111 12 13 14 15 16 17 18 19 20 21 22 23	$\begin{array}{c} -121\\ \\ \hline \\ 0\\ 0\\ -1\\ -3\\ -6\\ -9\\ -13\\ -17\\ -19\\ -21\\ -24\\ -27\\ -30\\ -33\\ -33\\ -37\\ -41\\ -43\\ -45\\ -47\\ -49\\ -52\\ -54\\ -59\\ \end{array}$	610170 5497189 223 382 1174 2838 6208 9622 17765 25205 19497 23502 37852 45730 54352 45730 54352 63718 93445 109565 74577 82302 90399 98868 144912 118965 263694	$\begin{array}{c} 1344904\\ 12409610\\ \hline 12409610\\ \hline 12409610\\ \hline \\ Ilinear H\\ \hline \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ $	$\begin{array}{r} 62226.7s\\ 375954.0s\\ \hline roperty\\ \hline T^{sol}\\ 0.1s\\ 0.2s\\ 0.3s\\ 0.4s\\ 1.4s\\ 3.9s\\ 55.2s\\ 452.1s\\ 787.2s\\ 161.9s\\ 570.3s\\ 742.3s\\ 2064.8s\\ 2508.2s\\ 58259.1s\\ 246564.5s\\ 15661.2s\\ 2447.7s\\ 2184.9s\\ 549.0s\\ 108.0s\\ 51.0s\\ 2745.4s\\ \end{array}$	80786           1008305           223           382           1174           2650           5200           7102           11785           10267           10732           15604           17506           19408           21310           30165           34755           22039           21760           21481           21202           29192           22489           50606	$\begin{array}{c} 220300\\ 2818702\\ \hline\\ 818702\\ \hline\\ 904\\ 1807\\ \hline\\ 5602\\ 11927\\ 21556\\ 27676\\ \hline\\ 43300\\ 52885\\ 35840\\ 38513\\ 38513\\ 38513\\ 38513\\ 38513\\ 38513\\ 38513\\ 38513\\ 76650\\ 74620\\ 103220\\ 115285\\ 73280\\ 74465\\ 75650\\ 76835\\ 106612\\ 82889\\ 180502\\ \end{array}$	$\begin{array}{r} 43099.3s\\ 287617.3s\\ 287617.3s\\ \hline \\ 287617.3s\\ \hline \\ 0.1s\\ 0.2s\\ 0.2s\\ 0.2s\\ 0.3s\\ 1.0s\\ 3.2s\\ 40.1s\\ 440.0s\\ 417.7s\\ 231.5s\\ 377.1s\\ 577.2s\\ 1918.9s\\ 23275.5s\\ 1918.9s\\ 23275.5s\\ 1918.9s\\ 23275.5s\\ 168923.4s\\ 12542.8s\\ 1987.3s\\ 2085.4s\\ 643.7s\\ 96.8s\\ 32.2s\\ 2440.3s\\ \end{array}$
27 Total Round 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24	$\begin{array}{c} -121\\ \\ \hline \\ 0\\ 0\\ -1\\ -3\\ -6\\ -9\\ -13\\ -17\\ -19\\ -21\\ -24\\ -27\\ -30\\ -33\\ -37\\ -41\\ -43\\ -45\\ -47\\ -49\\ -52\\ -59\\ -63\\ \end{array}$	610170 5497189 Var 223 382 1174 2838 6208 9622 17765 25205 19497 23502 37852 45730 54352 63718 93445 109565 74577 82302 90399 98868 144912 1189665	$\begin{array}{c} 1344904\\ 12409610\\ \hline 12409610\\ \hline 12409610\\ \hline \\ Ilinear If\\ 935\\ 1900\\ 5879\\ 12856\\ 24811\\ 34583\\ 58536\\ 77401\\ 57676\\ 68269\\ 107623\\ 127067\\ 148123\\ 170791\\ 246156\\ 283621\\ 191080\\ 209857\\ 229471\\ 249922\\ 364211\\ 297418\\ 653938\\ 603951\\ \end{array}$	$\begin{array}{r} 62226.7s\\ 375954.0s\\ \hline roperty\\ \hline T^{sol}\\ 0.1s\\ 0.2s\\ 0.3s\\ 0.4s\\ 1.4s\\ 3.9s\\ 55.2s\\ 452.1s\\ 787.2s\\ 161.9s\\ 5570.3s\\ 742.3s\\ 2064.8s\\ 2508.2s\\ 58259.1s\\ 246564.5s\\ 15661.2s\\ 2447.7s\\ 2184.9s\\ 549.0s\\ 108.0s\\ 51.0s\\ 2745.4s\\ 136591.4s\\ \end{array}$	80786           1008305           223           382           1174           2650           5200           7102           11785           15135           10267           10732           15604           19408           21310           30165           34755           22039           21760           21481           21202           29192           22489           50606           500065	$\begin{array}{c} 220300\\ 2818702\\ \hline\\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ $	$\begin{array}{r} 43099.3\mathrm{s}\\ 287617.3\mathrm{s}\\ 287617.3\mathrm{s}\\ 287617.3\mathrm{s}\\ 287617.3\mathrm{s}\\ 0.2\mathrm{s}\\ 0.2\mathrm{s}\\ 0.2\mathrm{s}\\ 0.2\mathrm{s}\\ 0.3\mathrm{s}\\ 1.0\mathrm{s}\\ 3.2\mathrm{s}\\ 40.1\mathrm{s}\\ 440.0\mathrm{s}\\ 417.7\mathrm{s}\\ 231.5\mathrm{s}\\ 31.5\mathrm{s}\\ 31.5\mathrm{s}\\ 377.1\mathrm{s}\\ 577.2\mathrm{s}\\ 1918.9\mathrm{s}\\ 2327.5\mathrm{s}\\ 23275.5\mathrm{s}\\ 12542.8\mathrm{s}\\ 12542.3\mathrm{s}\\ 2085.4\mathrm{s}\\ 643.7\mathrm{s}\\ 96.8\mathrm{s}\\ 32.2\mathrm{s}\\ 2440.3\mathrm{s}\\ 106329.4\mathrm{s}\\ 106329.4\mathrm{s}\\ \end{array}$
$\begin{array}{c} 27 \\ Total \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\$	$\begin{array}{c} -121\\ \\ \hline \\ 0\\ 0\\ -1\\ -3\\ -6\\ -9\\ -13\\ -6\\ -9\\ -13\\ -17\\ -19\\ -21\\ -24\\ -27\\ -33\\ -37\\ -41\\ -43\\ -43\\ -43\\ -45\\ -47\\ -49\\ -52\\ -54\\ -59\\ -63\\ -66\\ \end{array}$	610170 5497189 Var 223 382 1174 2838 6208 9622 17765 2505 2505 37852 45730 54352 63718 93445 109565 74577 82302 90399 98868 144912 118965 263694 246015 215848	$\begin{array}{c} 1344904\\ 12409610\\ \hline 12409610\\ \hline \\ \textbf{Linear I}\\ \hline \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\$	$\begin{array}{r} 62226.7 \mathrm{s}\\ 375954.0 \mathrm{s}\\ 75954.0 \mathrm{s}\\ \mathbf{Property}\\ \hline \\ \hline \\ 10.1 \mathrm{s}\\ 0.2 \mathrm{s}\\ 0.3 \mathrm{s}\\ 0.4 \mathrm{s}\\ 1.4 \mathrm{s}\\ 3.9 \mathrm{s}\\ 55.2 \mathrm{s}\\ 452.1 \mathrm{s}\\ 787.2 \mathrm{s}\\ 161.9 \mathrm{s}\\ 570.3 \mathrm{s}\\ 742.3 \mathrm{s}\\ 2064.8 \mathrm{s}\\ 2508.2 \mathrm{s}\\ 58259.1 \mathrm{s}\\ 246564.5 \mathrm{s}\\ 15661.2 \mathrm{s}\\ 2447.7 \mathrm{s}\\ 2184.9 \mathrm{s}\\ 549.0 \mathrm{s}\\ 108.0 \mathrm{s}\\ 51.0 \mathrm{s}\\ 2745.4 \mathrm{s}\\ 136591.4 \mathrm{s}\\ 151105.9 \mathrm{s}\\ \end{array}$	80786 1008305 Var 223 382 1174 2650 5200 7102 11785 15135 10267 10732 15604 17506 19408 21310 30165 34755 22039 21760 30165 34755 22039 21760 21481 21202 29192 22489 500665 43424	$\begin{array}{c} 220300\\ 2818702\\ \hline\\ \\ \hline\\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\$	$\begin{array}{r} 43099.3s\\ 287617.3s\\ \hline \\ 287617.3s\\ \hline \\ 287617.3s\\ \hline \\ 0.1s\\ 0.2s\\ 0.2s\\ 0.2s\\ 0.3s\\ 1.0s\\ 3.2s\\ 40.1s\\ 440.0s\\ 417.7s\\ 231.5s\\ 377.1s\\ 577.2s\\ 1918.9s\\ 2327.5s\\ 19823.4s\\ 1987.3s\\ 2327.5s\\ 1987.3s\\ 12542.8s\\ 1987.3s\\ 2085.4s\\ 643.7s\\ 96.8s\\ 32.2s\\ 2440.3s\\ 106329.4s\\ 112890.8s\\ \end{array}$

		I	Different	ial Proper	·ty				
Dound	Round $\log_2 P_{opt}$		M <sub>sun</sub>			$M_{sim}$			
nouna	log <sub>2</sub> r <sub>opt</sub>	Var	Cnf	$T^{sol}$	Var	Cnf	$T^{sol}$		
1	0	239	902	0.8s	239	855	0.1s		
2	-1	857	3789	1.9s	857	3602	0.1s		
3	-3	2415	9778	2.6s	2131	8789	0.2s		
4	-6	6038	21495	4.2s	4518	17324	0.7s		
5	-10	13415	42361	6.4s	8655	30475	3.4s		
6	-15	26799	77020	24.4s	15359	49870	22.7s		
7	-21	49007	131244	163.8s	25627	77497	230.4s		
8	-30	108025	272406	5512.4s	54445	151910	5358.7s		
9	-39	159420	384536	149122.6s	76920	202360	145998.0s		
10	-49	243782	570615	1628937.4s	111848	283107	1323894.2s		
Total		609997	1514146	1783776.5s	300599	825789	1475508.5s		
			Linear	· Property					
Round	log Coropt		$M_{sun}$			$M_{sin}$			
rtound	$\log_2$	Var	Cnf	$T^{sol}$	Var	Cnf	$T^{sol}$		
1	0	335	1415	0.1s	335	1368	0.1 s		
2	0	574	2876	0.1s	574	2735	0.1 s		
3	-1	1766	8903	0.2s	1766	8482	0.2s		
4	-3	4278	19480	0.2s	3994	18071	0.2s		
5	-6	9376	37611	1.3s	7856	32692	1.1 s		
6	-9	14550	52439	12.6s	10750	42012	$10.5 \ s$		
7	-13	26885	88776	200.6s	17865	65780	180.4 s		
8	-18	46923	143128	4483.5s	28679	98698	$4025.3 \ s$		
9	-22	53435	154236	36875.5s	29685	98220	25305.9s		
10	-27	83859	232396	457549.1s	42863	137626	387357.7s		
11	-31	88445	237556	936813.7s	41505	130660	624957.1s		
12	-33	62940	166486	129785.2s	26008	83255	50454.2s		
13	-36	96992	253923	158613.9s	35328	115844	87626.0s		
14	-39	112318	290559	161359.4s	37094	122908	97441.6s		
Total		602676	1689784	1885695.4s	284302	958351	1277360.4s		
15	-43	-	-	-	50325	165960	268094.1s		

 $\textbf{Table 13.} \ \textbf{Experimental results of SPECK96}$ 

 Table 14. Experimental results of SPECK128

		D	ifferenti	al Proper	$\mathbf{ty}$		
Dound	$\log_2 P_{opt}$		M <sub>sun</sub>			Msim	ı.
nouna	log <sub>2</sub> r <sub>opt</sub>	Var	Cnf	$T^{sol}$	Var	Cnf	$T^{sol}$
1	0	319	1206	0.1s	319	1143	0.1s
2	-1	1145	5069	0.1s	1145	4818	0.1s
3	-3	3231	13090	0.3s	2851	11765	0.3
4	-6	8086	28791	1.0s	6054	23212	0.7s
5	-10	17975	56761	3.5s	11615	40875	4.2
6	-15	35919	103228	36.7s	20639	66958	30.3
7	-21	65695	175932	343.8s	34475	104153	286.3
8	-30	144825	36520	9874.4s	73325	204390	9773.7s
9	-39	213740	365206	274980.4s	103720	272600	247510.6s
Total		490935	1264859	285240.3s	254143	729914	257606.3s
				Property			
Round	$\log_2^{Cor_{opt}}$		M <sub>sun</sub>			$M_{sim}$	
	-	Var	Cnf	$T^{sol}$	Var	Cnf	$T^{sol}$
1	0	447	1895	0.1s	447	1832	0.1s
2	0	766	3852	0.2s	766	3663	0.1s
3	-1	2358	11927	0.2s	2358	11362	0.2s
4	-3	5718	26104	0.4s	5338	24215	0.3s
5	-6	12544	50411	3.6s	10512	43828	2.9s
6	-9	19478	70295	23.2s	14398	56348	18.1s
7	-13	36005	119016	463.5s	23945	88260	308.5s
8	-18	62859	191896	10263.7s	38471	132490	8422.5s
9	-22	71595	206796	11079.5s	39845	131900	8468.6s
10	-27	112371	311596	355623.7s	57551	184858	253834.6s
Total		324141	993788	377458.1s	193631	678756	271055.9s
rotai							