



**29<sup>th</sup>** Annual **INCOSYMP**  
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Orlando, FL, USA  
July 20 - 25, 2019

# SET-BASED DESIGN OF VERIFICATION STRATEGIES

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*systems*



What is the HARDEST thing **engineers** do?



James A. Azano  
Herold C. Manock  
Daniel Kottke  
Bury Carl  
D. L. Cannon  
D. L. Cannon

Charles J. Wymore  
Bill Atkinson  
Vick Millidge

Bruce Horn  
George Crow  
Rod Holt

Andy Hertzfeld  
Angeline Lo  
Ewen

James A. Azano  
HAP HORN

W.E. McCammon  
Burrill Smith  
Jef Raskin

Langhill  
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Steven Jobs

Chris Robertson  
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Larry Kenyon  
Martin P. Haller  
Calotte Oakland

Larry J. Jell  
Mike Boich

Lynn Sakahachi  
Benjamin L. Fung

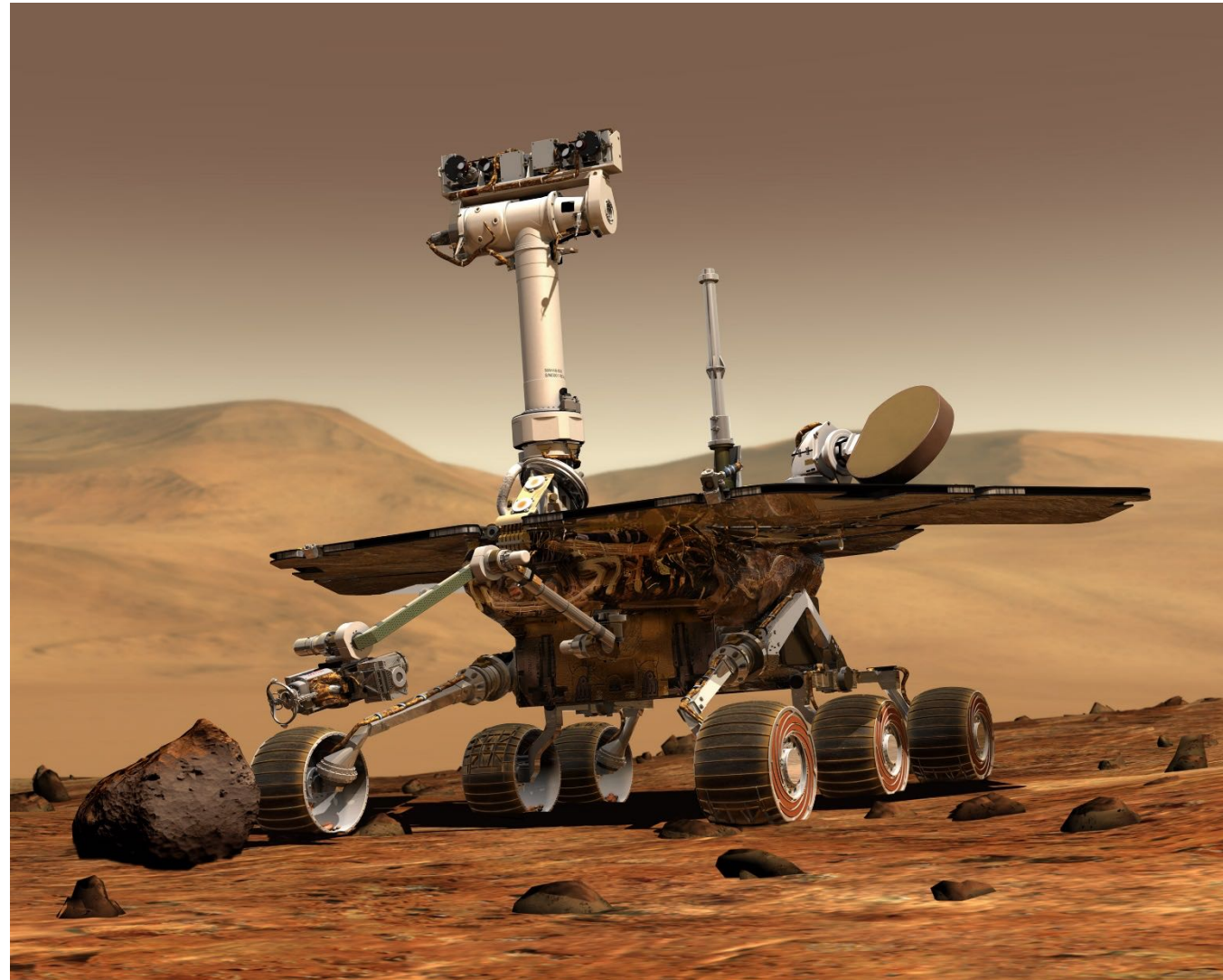
Bill Fernandez  
Donna Denman  
Patti King

David H. Reed  
Ronald W. Nicholson  
Matt Carter  
Robert L. Bellville

Ray  
Bry

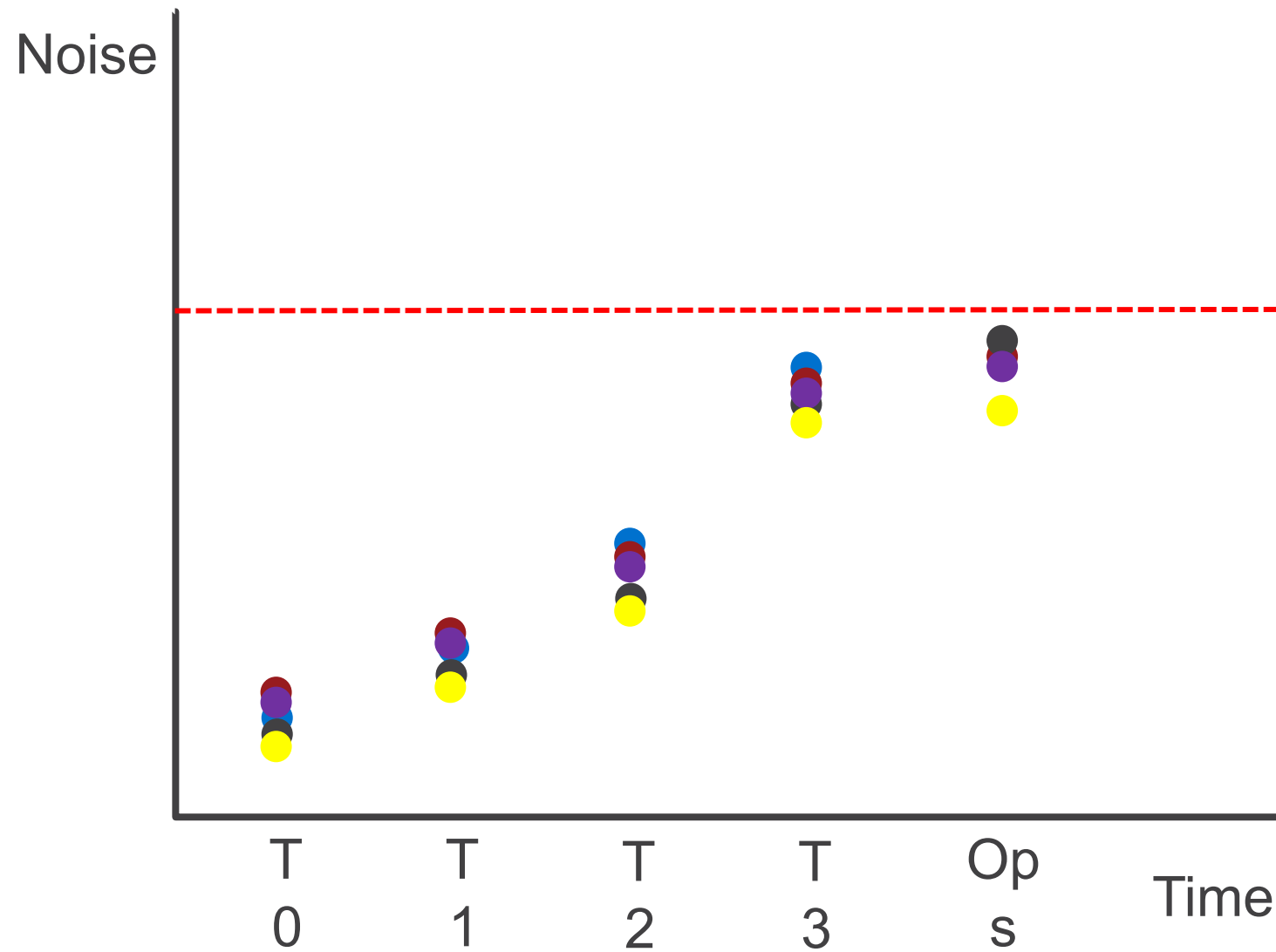
Randy Wigginton

Sandra Wilkins  
Michael Munoy







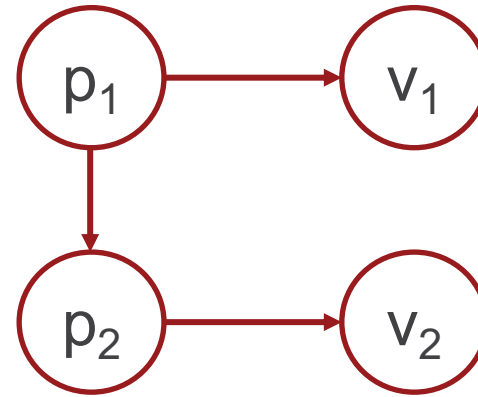






A verification activity is objective.  
The confidence we gain is not.

Verification is not objective.  
Verification is an **agreement**.



$p_1$ : physical properties of model

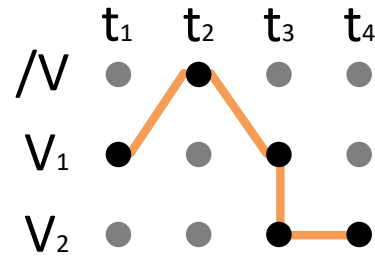
$p_2$ : mass of final product

$v_1$ : estimated mass with model

$v_2$ : measured mass of final product

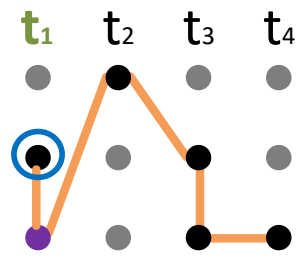


# Current paradigm



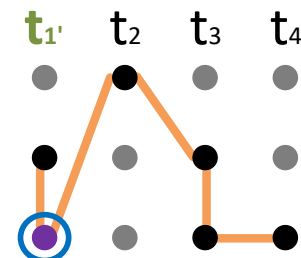
This is the **optimal** strategy, agreed upon contractual signature.

$$C_{\text{original}} = \sum C_{\text{black dots}}$$



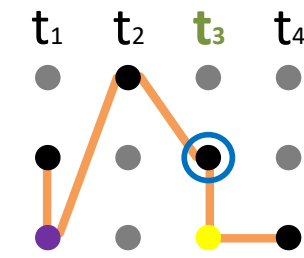
Circled activity showed **low margin**. Unplanned purple activity needs to be added through **CR**.

$$C_{\text{final}} = C_{\text{original}} + \Delta_{\text{purple}}$$



Circled activity showed **nominal margin**. No change to strategy.

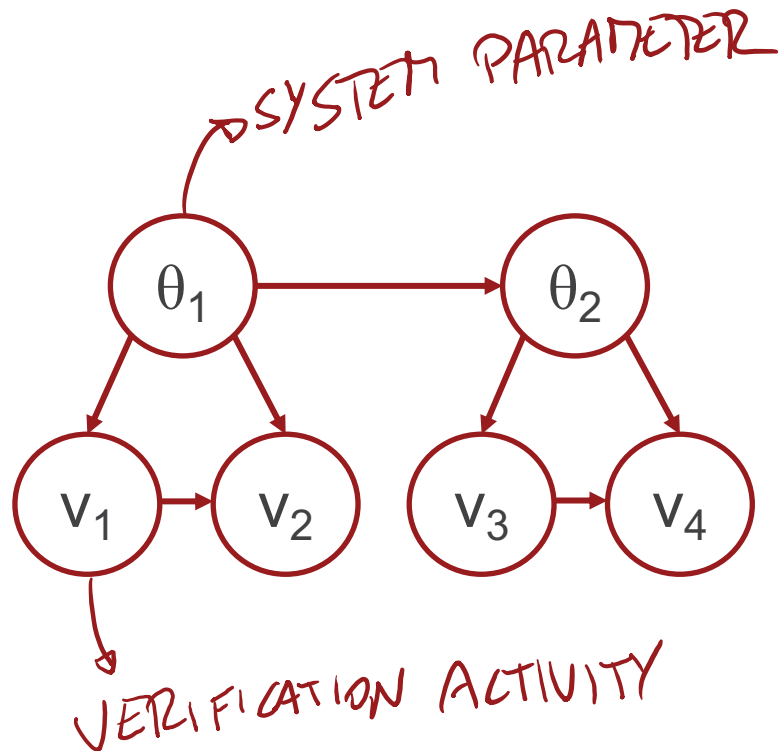
$$C_{\text{final}} = C_{\text{original}} + \Delta_{\text{purple}}$$



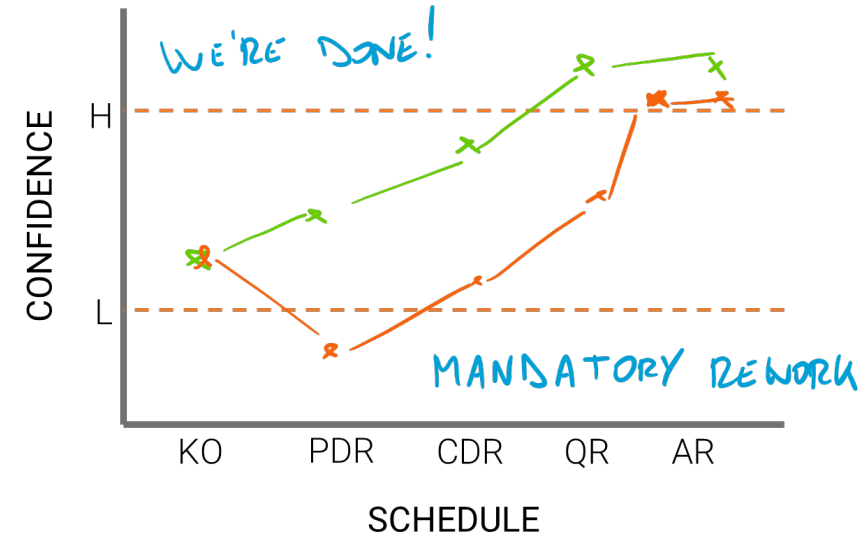
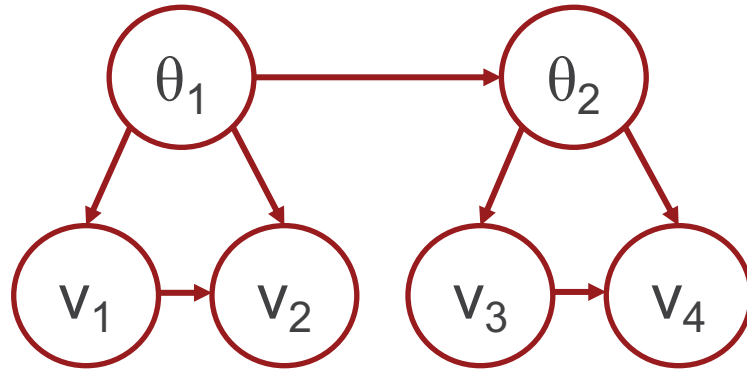
Circled activity showed **ample margin**. Yellow activity provides no value, but it is executed.

$$C_{\text{final}} = C_{\text{original}} + \Delta_{\text{purple}}$$

# Case Study



Watts → Kelvin



$$E[C_T(S)] = \sum_{V \in \mathbf{V}} C_V(V) + \sum_{k=1}^o \sum_{j=1}^n \sum_{v \in L(T_j)} P(v) P(\theta_{jk} | v) \delta(\theta_{jk} | v) C_R(\theta_{jk}) + \sum_{k=1}^o \sum_{v \in \mathbf{V}^*} P(v) P(\theta_k = e | v) C_I(\theta_k = e)$$

↓ EXECUTION
↓ RERWORK
↓ ERROR



# Optimization Algorithm

**STEP 1** Determine optimal verification strategy at Time 1.

**STEP 2** Choose first (timewise) verification activity (or subset of verification activities).

**STEP 3** Execute activity and update Bayesian network.

**STEP 4** Determine optimal remaining verification strategy and return to Step 2.

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Dynamic Contracting Strategy ( $N$ ,  $ACT$ ,  $C$ )

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Input:  $N$  — Bayesian Net;  $ACT$  — Activity Constraint Table

$C$  — Cost Table

Output:  $S_{opt} = \{V_{opt}(T_1), V_{opt}(T_2), \dots V_{opt}(T_n)\}$

1: **For**  $t$  in  $T_1 : T_n$

2:     Generate all feasible paths  $VS_{ti} = \{S_1, S_2, \dots S_m\}$  at time point  $t$ ;

3:     Evaluate the expected cost of all verification paths;

4:     Select the minimum one  $S = \{V_{opt}(T_1), V_{opt}(T_2), \dots V_{opt}(T_t), V(T_{t+1}) \dots V(T_n)\}$  and update the optimal path  $S_{opt} = \{V_{opt}(T_1), V_{opt}(T_2), \dots V_{opt}(T_t)\}$ ;

5:     Collect the results of  $V(T_t)$  and set the evidence adaptively;

6:     Update the Bayesian network and  $ACT$

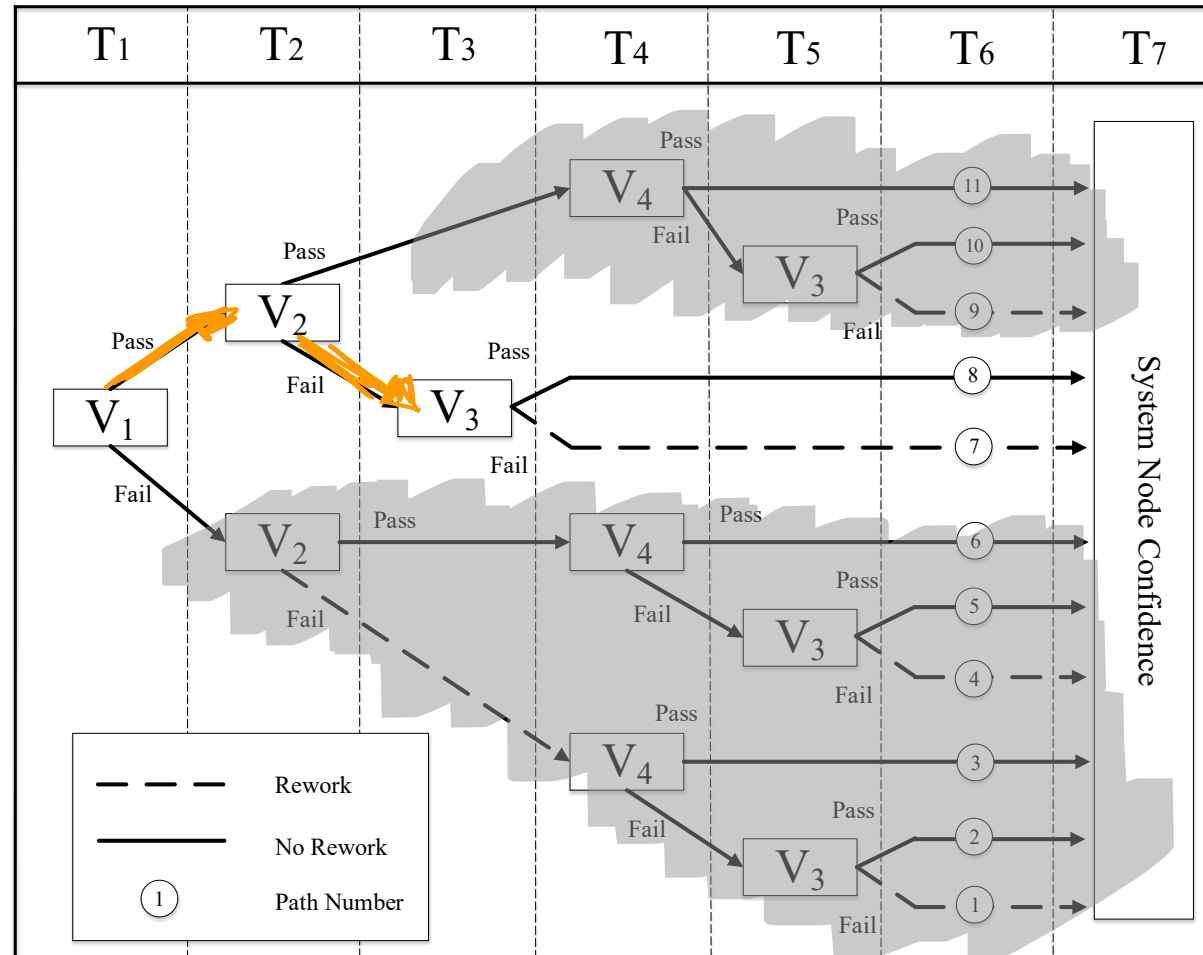
7: **End**

8: **Return** the optimal path  $S_{opt} = \{V_{opt}(T_1), V_{opt}(T_2), \dots V_{opt}(T_n)\}$

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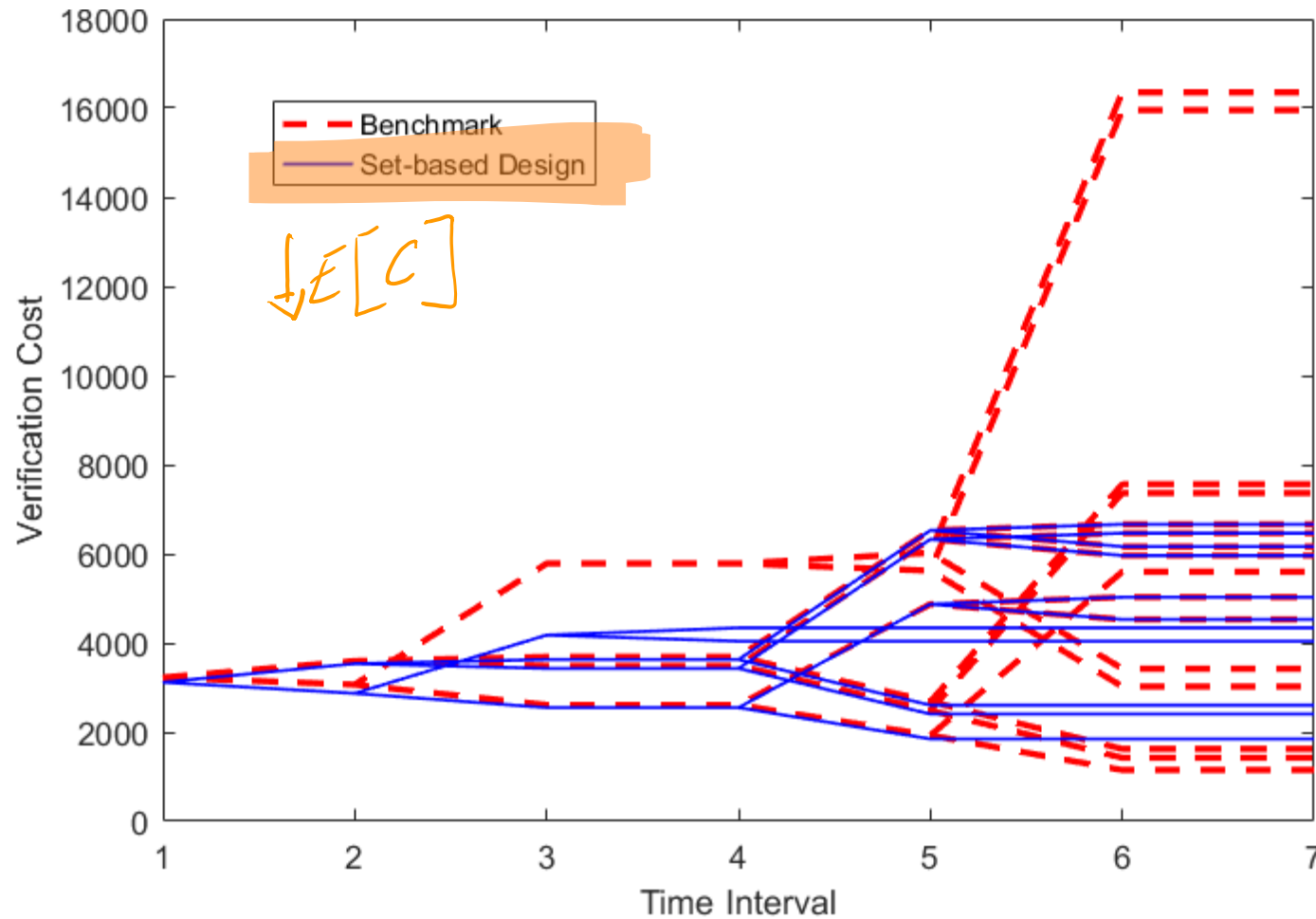


# Visualization of Set-Based Strategy





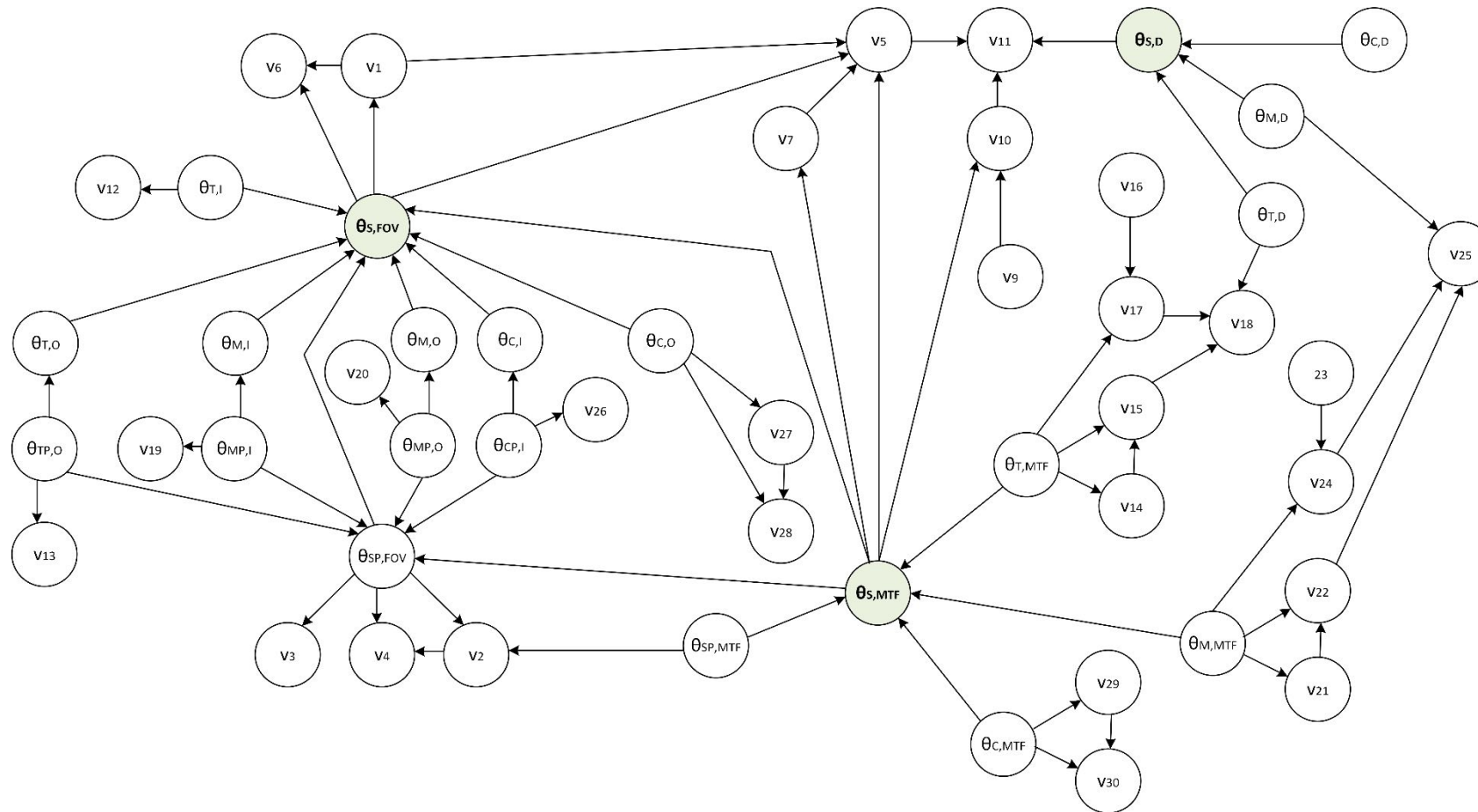
# Results



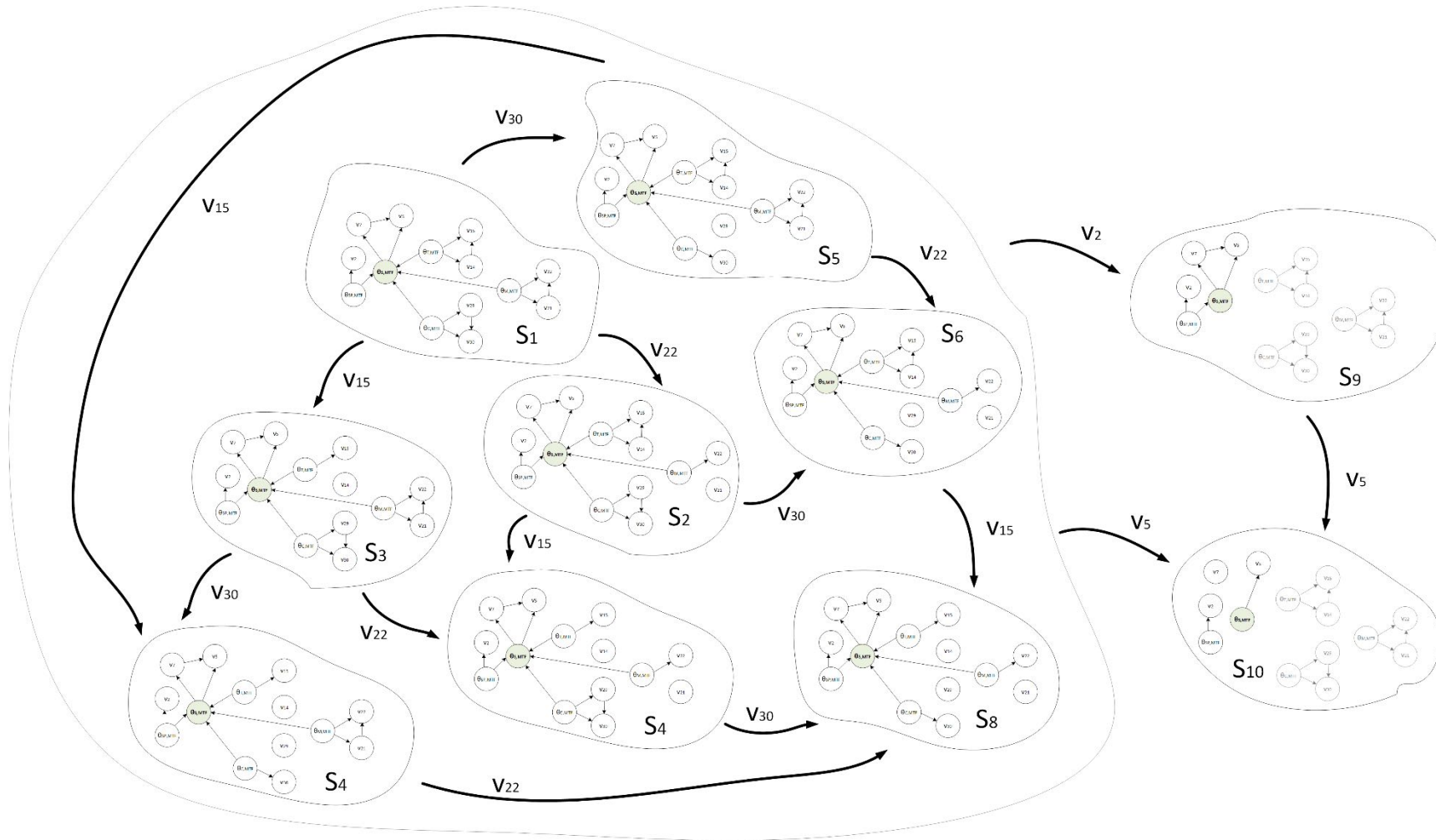
Expected Cost:

- Set-based Design:  
\$ 3,004k
- Benchmark:  
\$ 3,214k

# Currently working on this...



# Planning to work on this...



# Conclusion



CONTRACTING  
verification activities must be

Dynamic

Adjusted after results



Thank you for your attention!



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