Systems Engineering: Roles and Responsibilities

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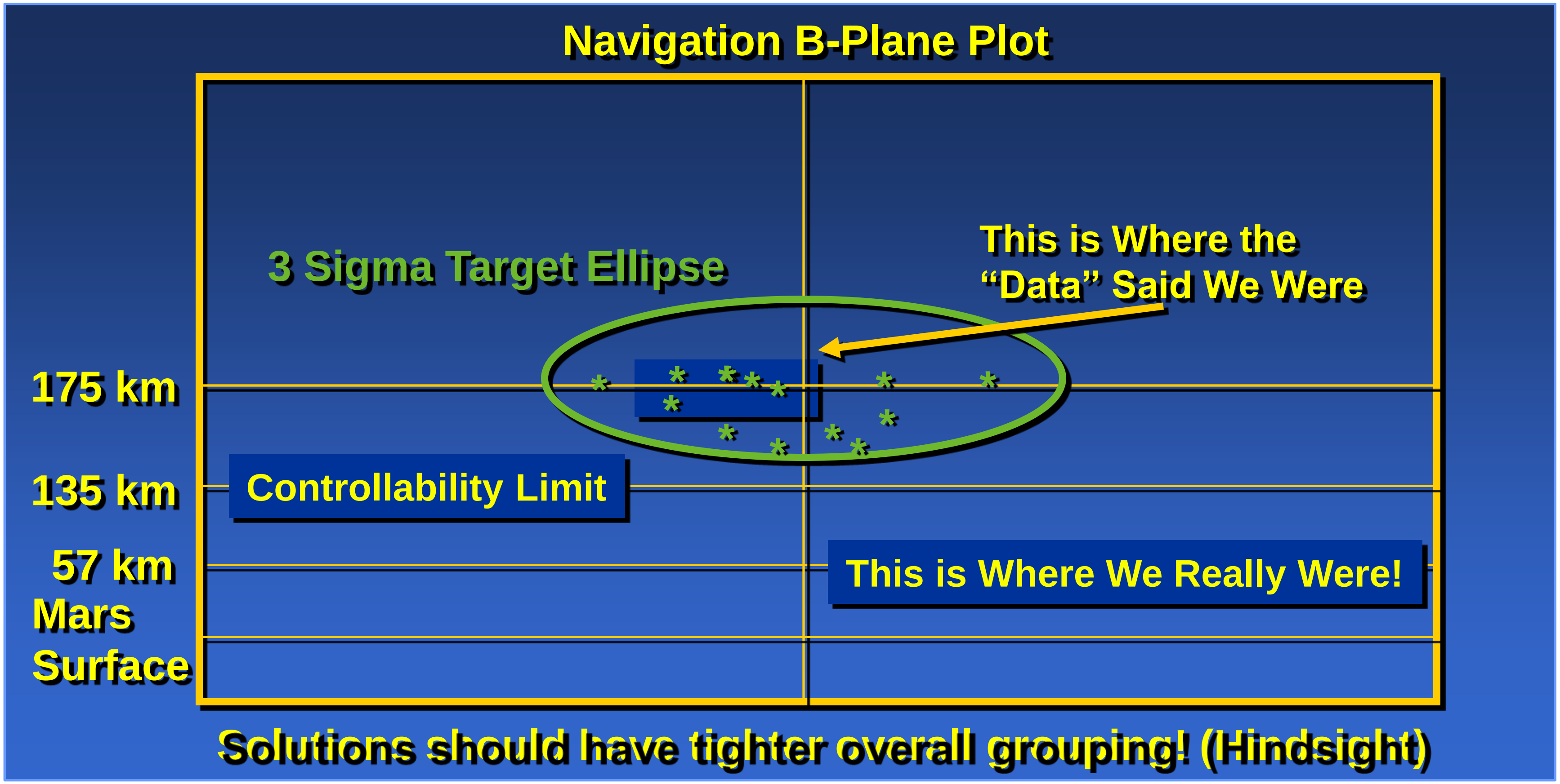
Making Decisions With Uncertainty

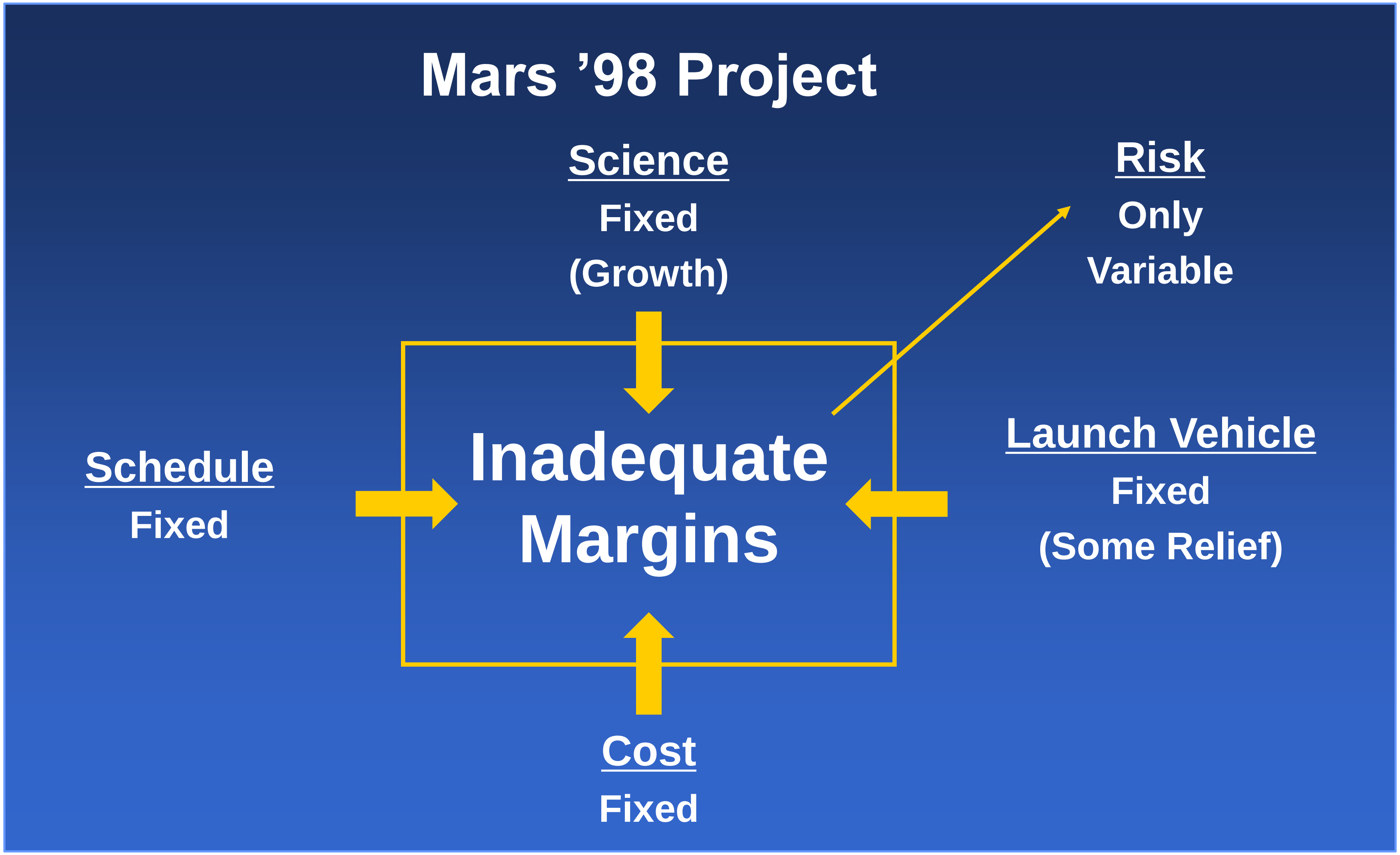
- Engineers are Relatively Good at Logical Decisions
  - The Problem is With the Assumptions …
- Testing the Assumptions is the Most Important Trait of a Good Systems Engineer -Remember You are the Easiest One to Fool
- In Most Cases, an 80% Solution is Good Enough, but not always!



Systems Engineering Key Lessons

- Truth of DeLuca’s Law (from Political Savvy)
  – [Space System development is] Not a rational system that happens to involve humans, but a human system attempting to act rationally
- Configuration control is good
  – Even very early in project life cycle
- All mistakes are stupid
  – We miss the obvious
- Test Like You Fly (TLYF)/Test at System Level cannot be the only verification approach
  – Need to do things right the first time (at lowest level)
- Distraction can be dangerous
  – We miss the critical while focused on the urgent
- Non-linear affect of requirements creep

Lessons Which We Must Not Re-Learn!



Systems Engineering Precepts

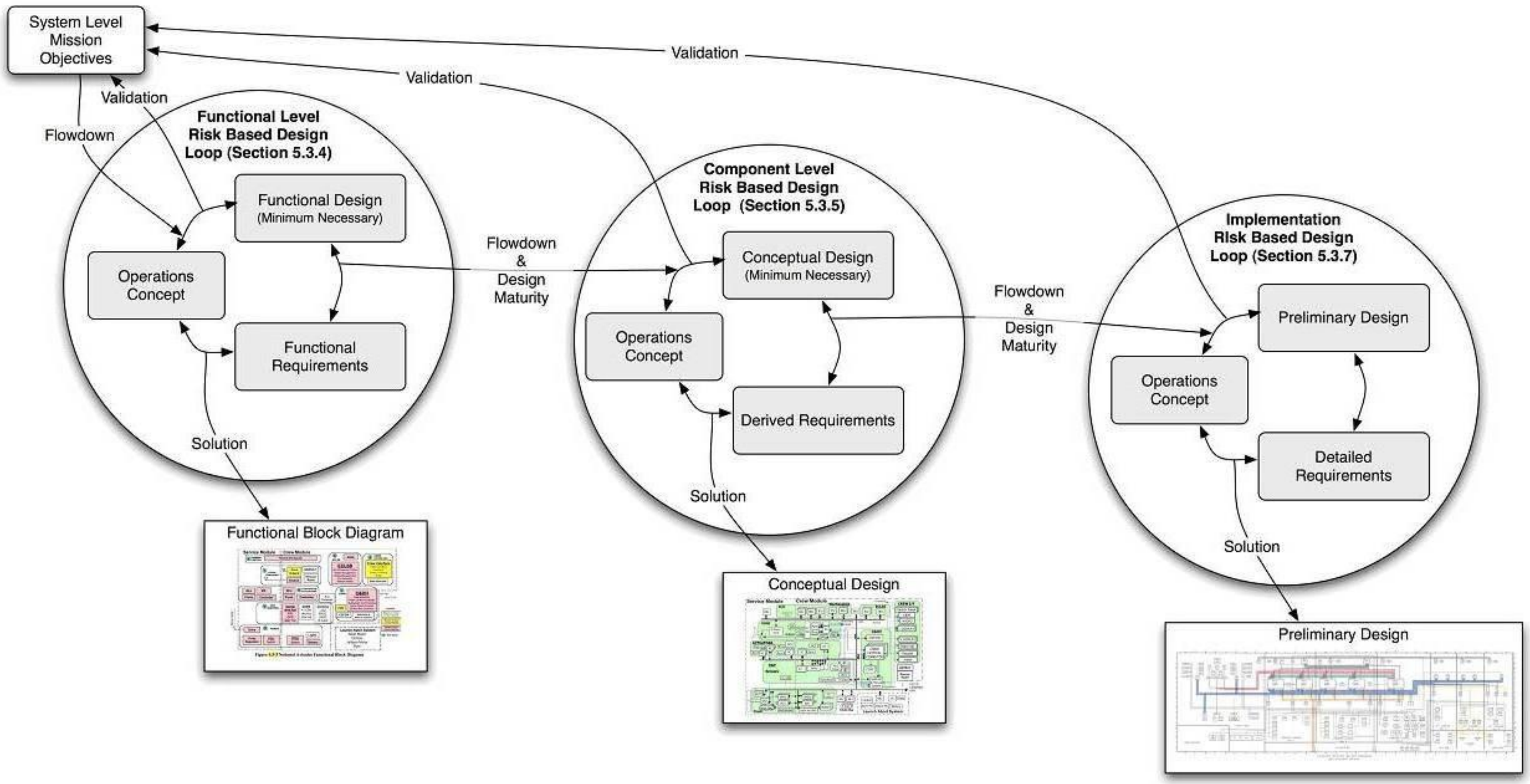
- **Working Definition: The art and science of guiding the end-to-end engineering of complex space systems**
  - **Art because it involves extensive people skills and leadership**
  - **Science because it requires rigorous applications of tools and methodologies**
- **Key Objectives**
  1. **Employ First Principles Approach**
     - **Keep the critical-to-customer requirements always in mind**
     - **Everything else supports these**
  2. **Bring the entire project together**
     - **Big Tent, end-to-end, Diversity of ideas are good**
  3. **Vertical and horizontal integration**
  4. **Verification and validation**
     - **Separate disciplines**
     - **Little "i" V&V**

Systems Engineering Leads the Technical Execution of the Project!

- **Accomplished by Establishing the Technical Rhythm (Cadence) by Which the Project Marches**
- **This is the Weekly/Periodic Procedure that:**
  - **Controls Changes to the Technical Baseline**
  - **Matures the System through the Project Life-Cycle**
  - **Reduces/Accepts System Risk**
  - **<u>Directly</u> affects the Life-Cycle Cost Outcome**
- **Needs to be In-Place at Contract Start**
  - **Can be Tailored for Early Phases in the Life-Cycle**
- **Must Not Strangle the Project with Many Meetings**
  - **Attendance and Periodicity Carefully Architected**
  - **Everyone Hates Long, Fruitless, Unstructured Meetings**
    - **Except for Dilbert's "Meeting Moth" ….**

Systems Engineering P³

- **People, Processes, Products**



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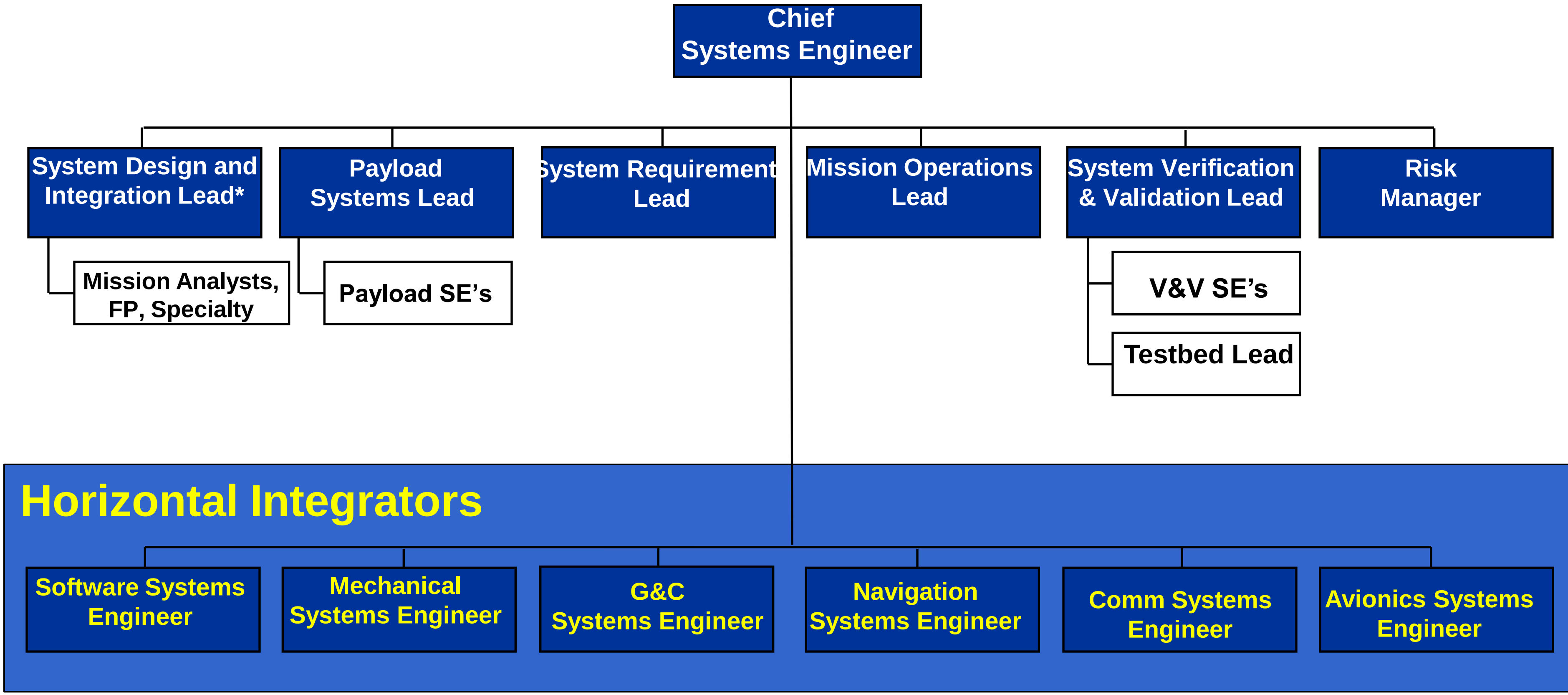
People

- Leaders
- Integrators (Subsystem Superstars)
- Analysts
- Open Culture
- Inclusive

Example Systems Engineering Organization



Developing System of Systems Engineers		
General Characteristics	**Elements of Training**	**Seen in Practice**
Generalist, Architect, Firefighter	On the job training, how work gets done, mentoring	Know what they know and what they don't know
Intellectually curiosity, self-confident, energetic	Hands-on experience, end-to-end ownership develops judgment	Big picture, end-to-end, concept to operations, the *Systems View*
Big picture oriented, end-to-end and concept-to-operations thinker	Working across subsystems and with new technologies	Tracks and knows state of key technical /program resources and their margin
Comfortable with change and uncertainty	Classes for fundamentals, familiarity with tools, lessons learned	Understands difference between requirements & capabilities
Good communicator and listener	Learn processes as useful tools	Knows processes are tools, and not an end to themselves
Healthy paranoia	Multiple job and project experience	Builds in robustness, overlapping capability
Team player, works well as part of a diverse team	Test and tune decision making skills and judgment	Conducts objective trade studies, balances technical and programmatic

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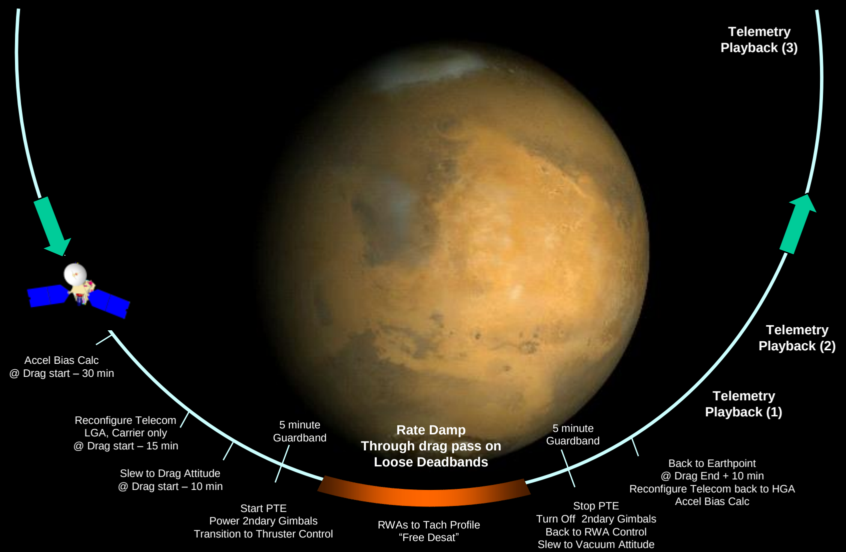
Processes

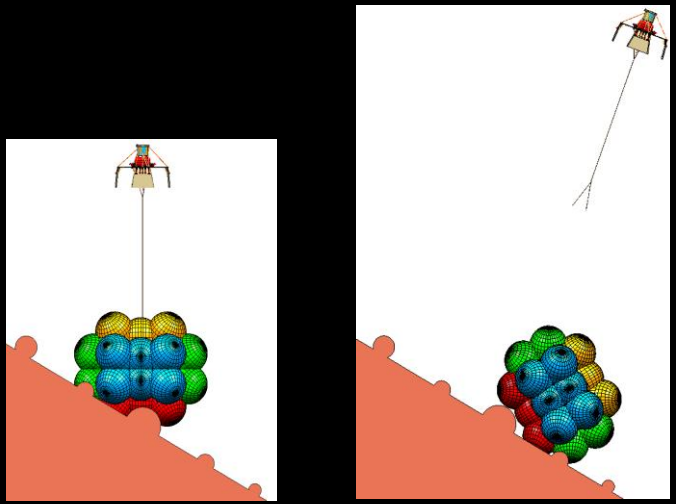
- Baseline Control
- V&V (as separate processes)/“i” V&V
- Configuration Control
- Trades
- System Design Team/Engineering Change Board

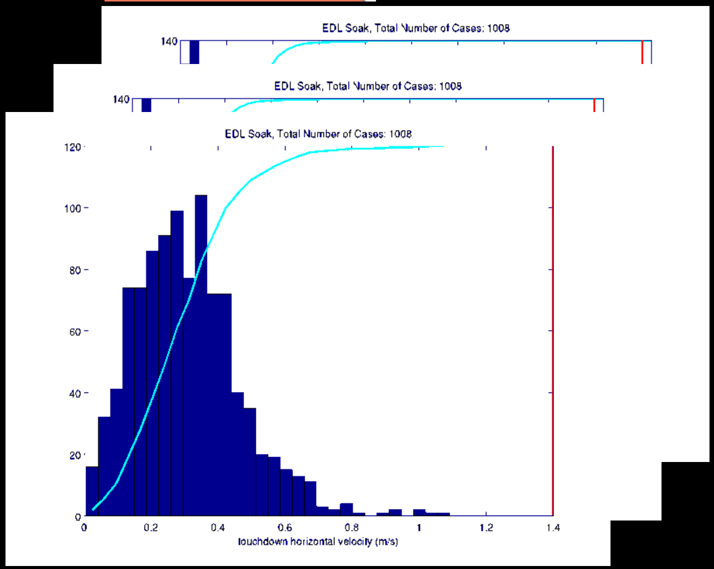
Comparing Roles of the PI/PM to SE

	Project Management	SE Management
Planning	Project Management Plan, Integrated Master Plan & Schedule (IMP/IMS)	Systems Engineering Management Plan (SEMP) IMP / IMS (tech), Processes
Organizing	Project Org. Chart Work Breakdown Structure (WBS)	SE Org. Chart Working Groups, Reviews, Risk Management
Staffing	Project Manpower Plan, Roll-on/Roll-off, Project Office Staff	SE Recruiting, Training, Team Building
Controlling	Earned-Value Management System (EVMS), Project Reviews, Monthly Management Reviews	EVMS, Eng. Change Board (ECB), Tech Metrics, Baseline Control, System Design Team Meetings
Directing	Policies, Procedures, Training, Supervising, Performance Appraisals	Reqt's Development, Verification and Validation, Performance Appraisals

"Danger Will Robinson! Danger …"

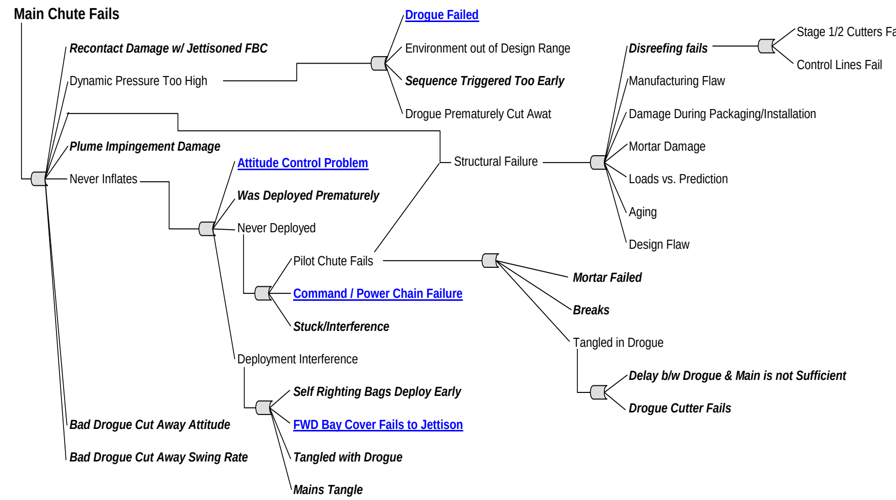






Why can't the system be calculated to a first-order on a white board? Why only by Sims and Monte Carlo's …

Image Credits: NASA/JPL



There are thousands of ways to fail … most have not been explored

Technical Performance Measures Management

System Resource/Mission Phase	SDR	PDR	CDR	ATLO start	Launch
Mass	25%	20%	15%	10%	3%
Energy/Power	30%	20%	15%	10%	10%
Power Switches	35%	30%	20%	15%	10%
CPU Utilization	75%	60%	50%	30%	20%
Memory					
SSR (Bulk storage)	30%	20%	20%	15%	10%
DRAM	75%	60%	50%	30%	20%
NVM (Flash)	75%	60%	50%	40%	30%
SFC EEPROM	75%	60%	50%	40%	30%
Avionics					
Serial Port Assignments	3	3	2	2	2
Bus Slot Assignments	3	2	2	1	1
Discrete I/O	30%	20%	15%	12.50%	10%
Analog I/O	30%	20%	15%	12.50%	10%
Earth to S/C Link(C)	3 db	3 db	3 db	3 db	3 db
Link Margin Bit Error Rate (3 sigma)	1.00E-06	1.00E-05	1.00E-05	1.00E-05	1.00E-05
Bus Bandwidth	60%	60%	55%	55%	50%
Mission Data Volume	20%	20%	15%	10%	10%
ASIC/FPGA Gates Remaining	40%	30%	20%	15%	10%
Crew IVA Time	40%	30%	20%	10%	10%

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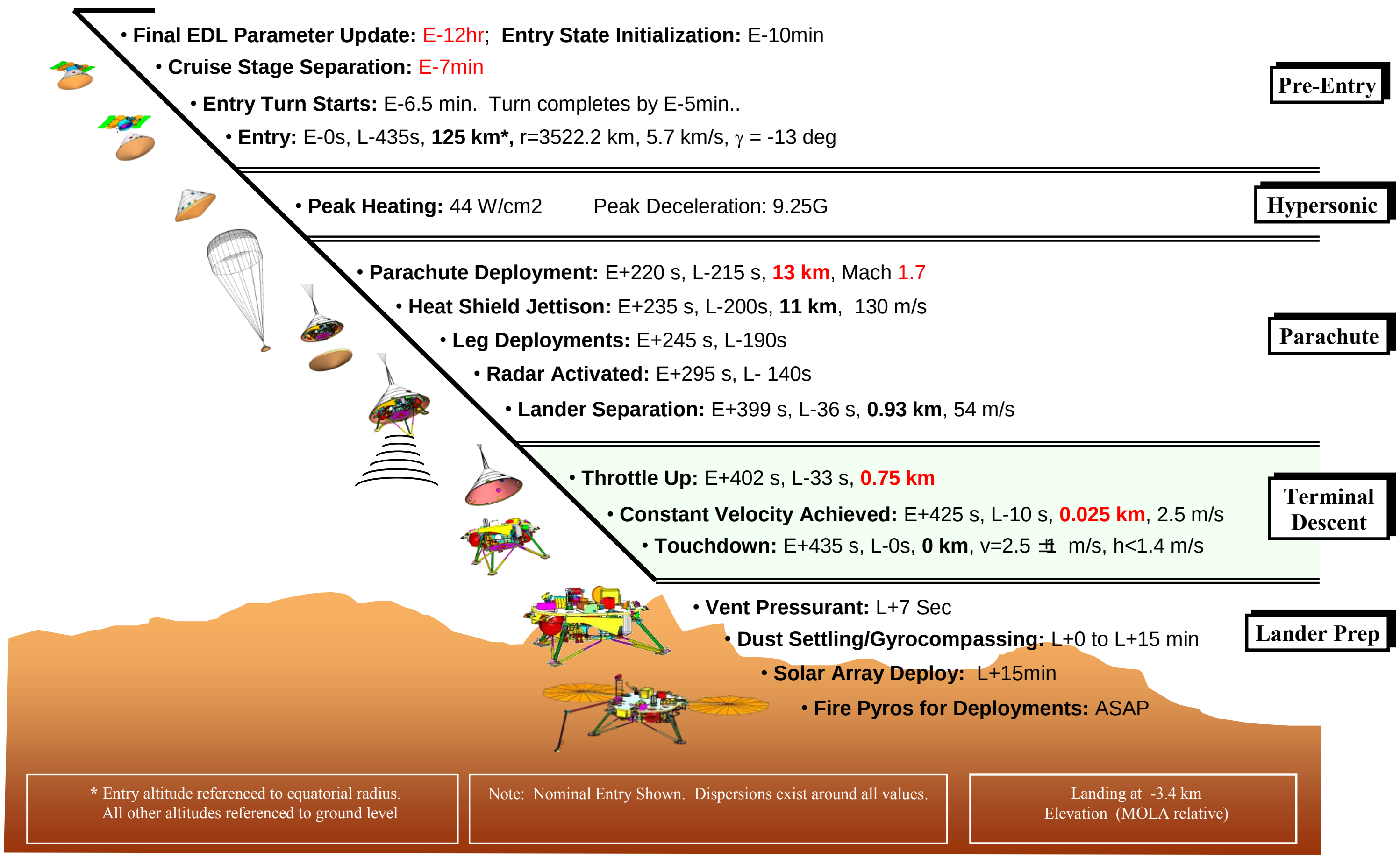
Products

- Design Reference Mission (OpsCon or CONOP)
- Master Equipment List
- Technical Performance Measures (TPMs)
- Requirements and Verification Database (DOORS)
- ICDs
- System Failure Mode and Effects Analysis (Fault Tree approach is best practice)
- Risk Reduction Test Program
- Numerous Systems Analyses



Example of Time-Domain CONOP/DRM, Phoenix Mars Scout Entry, Descent and Landing (NASA)

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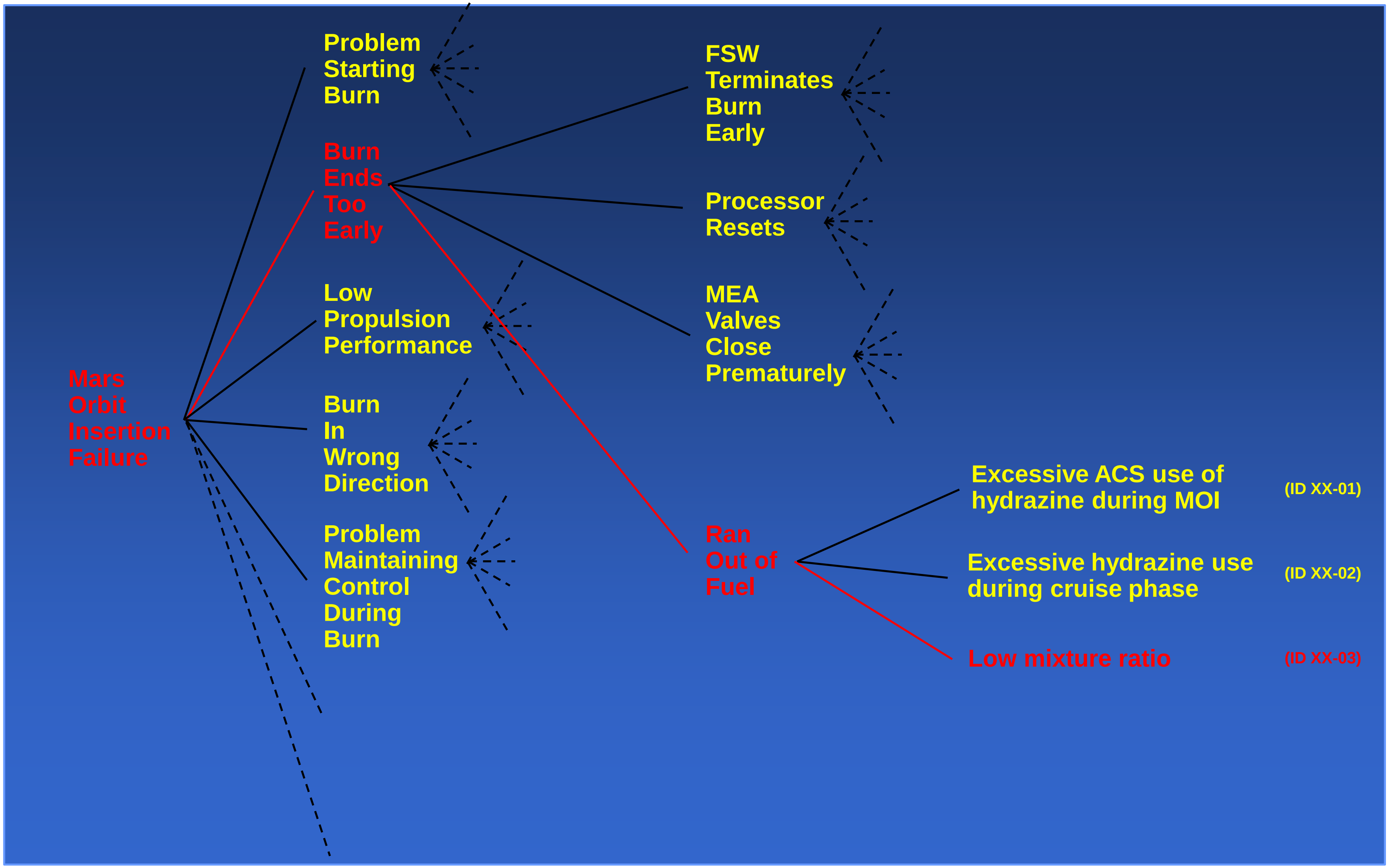
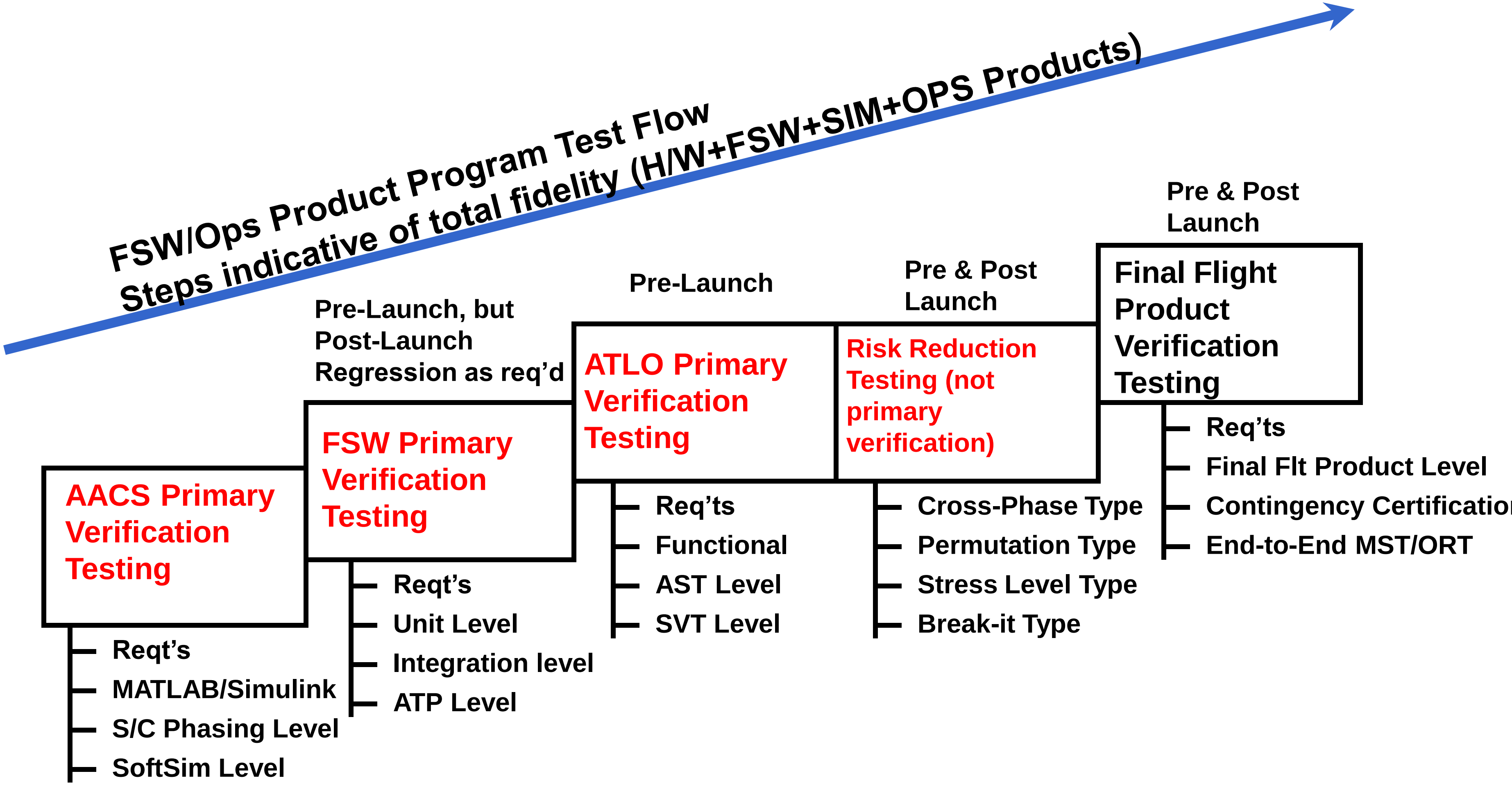
Fault Tree Mapped Effects to Potential Causes



Risk Reduction Testing Played Huge Role



Some SE-Specific Management Pitfalls

- Everybody is a Systems Engineer
- Only Complex Interfaces Need Managing
- Requirements Creep Only Comes From the Customer
- Government/Customer Furnished Equipment
- SE is Only Level-of-Effort for Earned-Value Management
- The SEMP (System Engineering Management Plan) is for simps!
- Technical Rules! Cost and Schedule are secondary …
- There are Totally Unbiased Recommendations
- The Project Manager can Double as the Lead SE or a Project Engineer