

# An Assessment of Risk Lists and Categorization at Major Milestones Across the Lifecycle of NASA Missions

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The Aerospace Corporation

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# Outline



- Introduction
- Milestone Analysis
- Monetization of Threat
- Individual Mission Deep Dive Deep-Dive
- Check List and Recommendations
- Summary

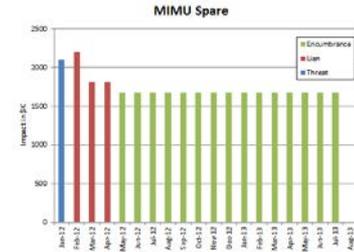
# Study Goal and Approach

- Goal
  - *Create a defensible, historical driven, risk identification checklist for projects to use during their JCL analysis at KDP-C specifically, as well as provide benchmark for other specific milestones (CDR and SIR)*
  - *Limited to the identification and stratification of historic risks*
    - Does not specifically address the impacts from a cost and schedule perspective
- Approach
  - *Collect and summarize detailed risk lists for NASA missions*
    - Milestones taken from PDR, CDR and SIR
  - *Develop database of risk lists, categorize rating/type of risks at each milestone and other statistics*
  - *Develop checklist and recommendations for developing threat list for future JCL analysis*

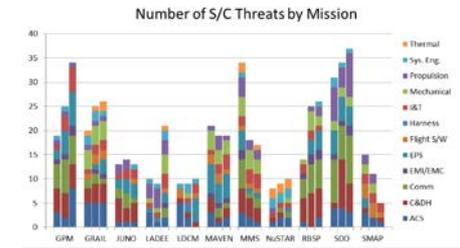
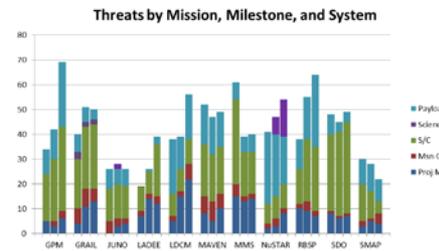
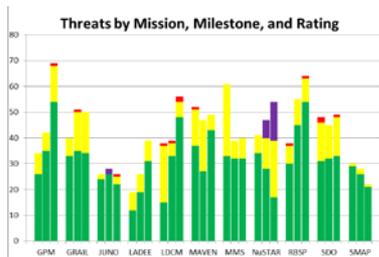
# Process Overview

## Data Collection & Assessment

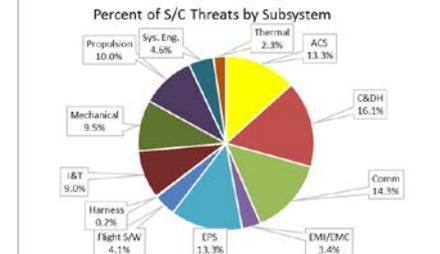
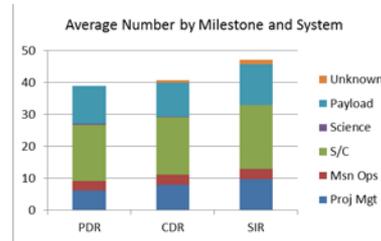
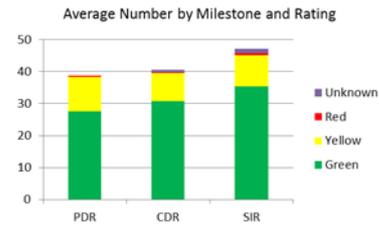
Mission	Program	Center	Destination	Theme	Num Threa
GPM	Earth Sys.	GSFC	Earth	Earth Science	145
GRAIL	Discovery	JPL	Moon	Planetary	141
JUNO	New Frontiers	JPL	Jupiter	Planetary	80
LADEE	Lunar Quest	ARC	Moon	Planetary	89
LDCM	Landsat	GSFC	Earth	Earth Science	217
MAVEN	Mars Explor	GSFC	Mars	Planetary	148
MMS	Solar Terres	GSFC	Earth	Helio	158
NuSTAR	Explorer	JPL	Earth	Astro	142
RBSP	LWS	GSFC	Earth	Helio	157
SDO	LWS	GSFC	Earth	Helio	142
SMAP	SMD	JPL	Earth	Earth Science	80



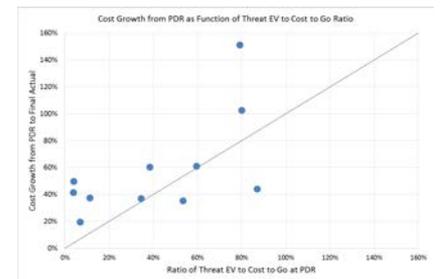
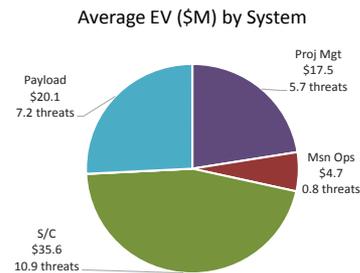
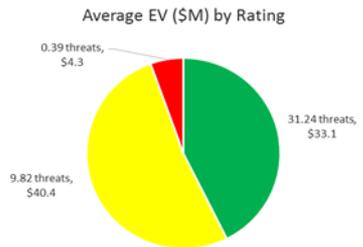
## Risk/Threat Categorization



## Threat Averages & Distributions



## Threat Quantification



# Study Outcome

- Observations
  - *Risk lists vary substantially with typically only top “N” risks reported*
  - *Distribution includes 45% S/C, 30% instruments, 20% project mgt, 5% other*
  - *Project risks typically focus on element of primary responsibility of Center*
  - *Number of threats increase over time led by S/C I&T & EPS*
  - *5x5 classification for quantifying cost/schedule impact varies by Center*
  - *Unclear if projects actually uses Center quantification guidelines for 5x5 as there is a disconnect with calculated value vs, project reported values & JCL*
- Recommendations
  - *Require a full, clearly named, project-level risk list at each milestone with consistent risk ID naming/tracking*
  - *Require that all risks with cost/schedule impacts are recorded as threats*
  - *Require consistent tracking from risks to threats to liens to encumbrances*
  - *Provide NASA-level guidance of 5x5 cost/schedule impact quantification*
  - *Provide risk database and guidelines to SRB & JCL teams*

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# Mission Set

- Statistics

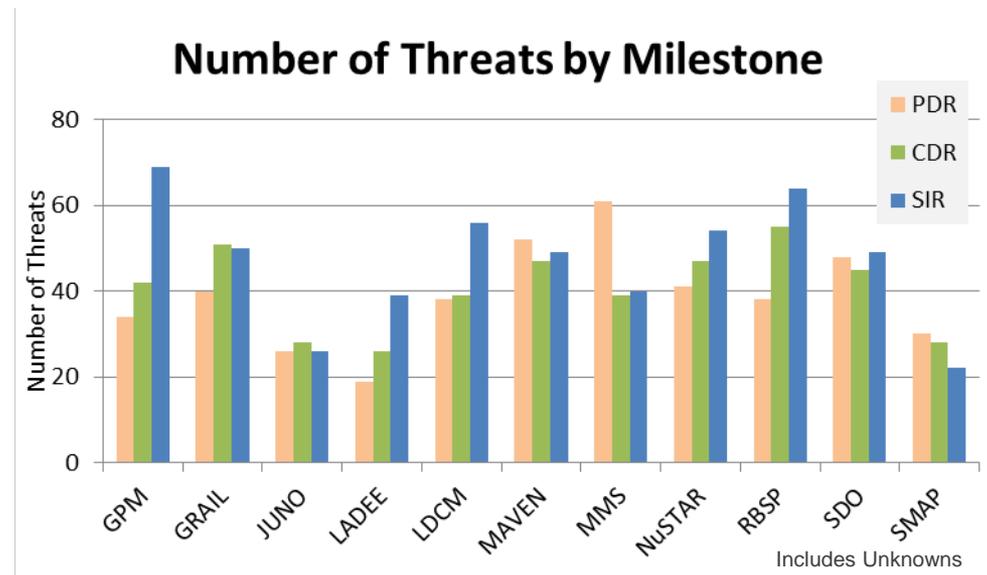
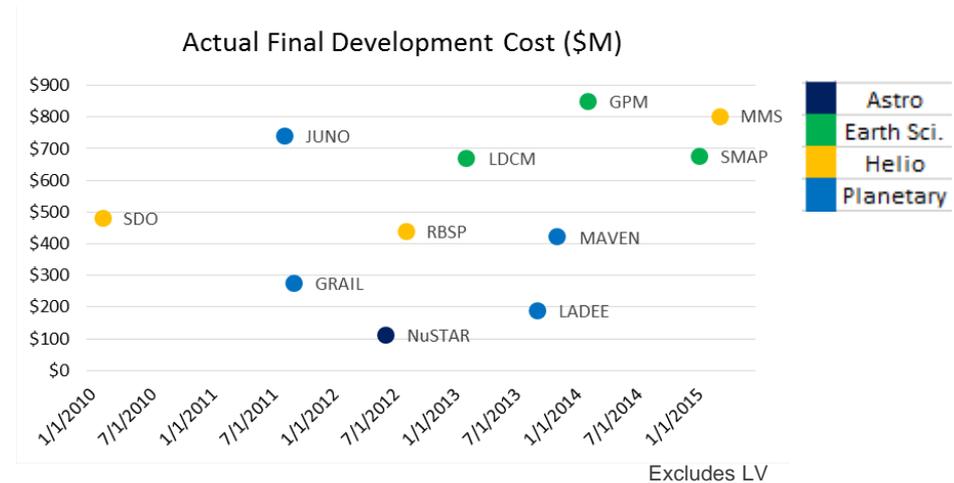
- 11 Missions
- 1500 individual risk entries
- 1050 unique mission risks

- Mission Characteristics

- Diverse themes
- Launch dates from 2010 through 2015
- Cost range from \$100M to \$800M

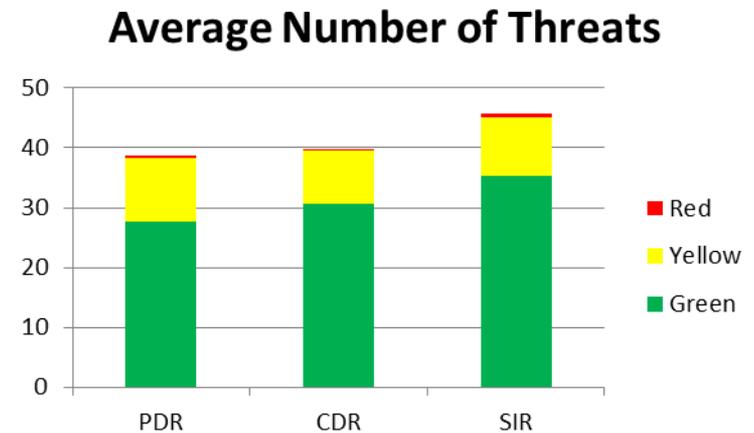
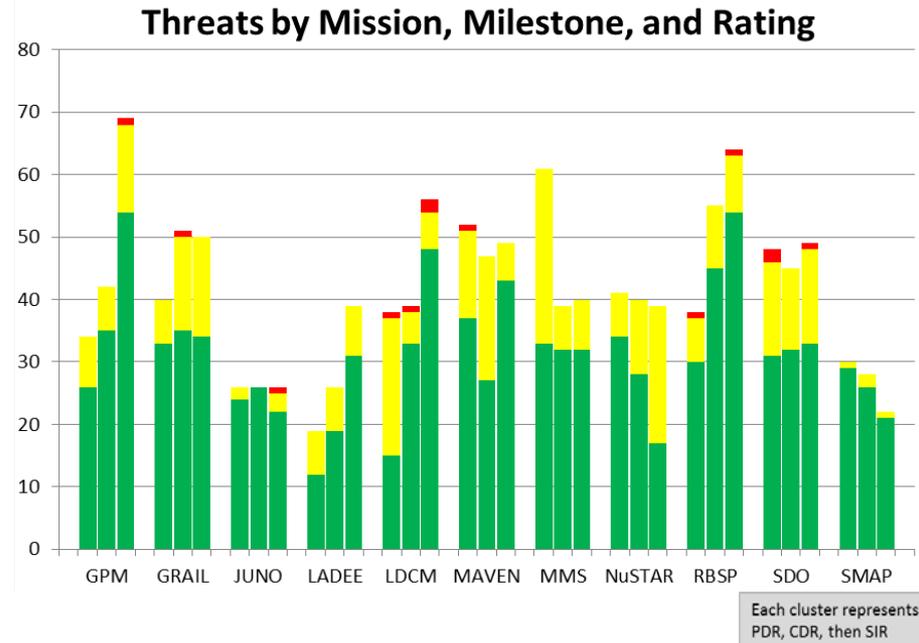
- Threats

- Wide range in count
  - Mid 20's to > 50
- Some Unknown due to lack of Likelihood, Consequence or Title
  - Removed for following analysis



# Milestone Analysis Summary – Threat Rating

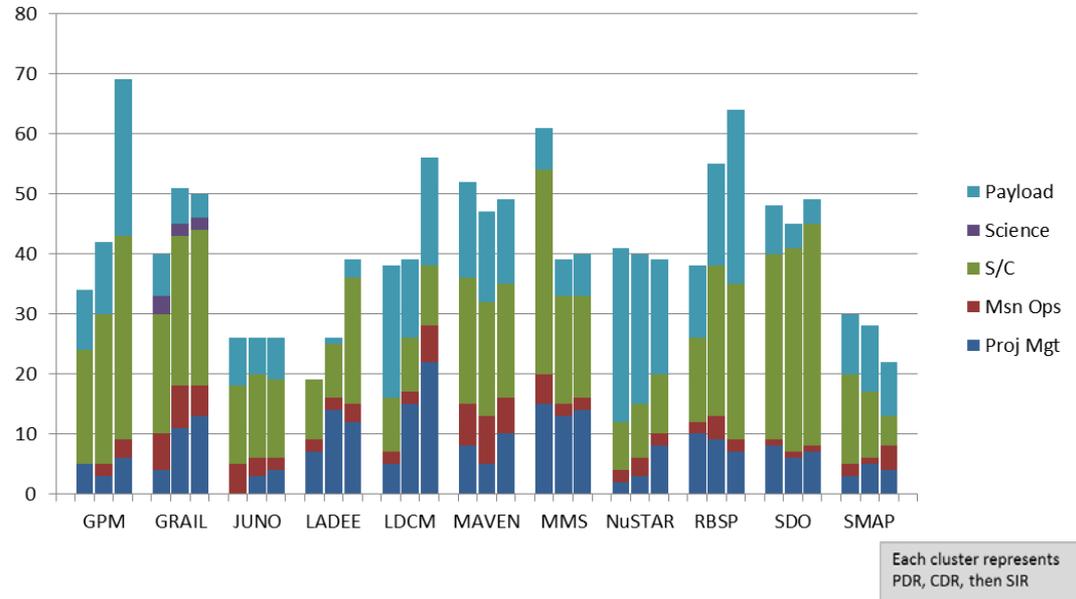
- Trend/Observations
  - *Increasing number of Green*
  - *Steady number Yellow*
  - *Very few Red*
  
- Recommendations/Check List
  - *Full project-level risk list at each milestone*
    - Does not have to be presented but should be part of package
  - *Total number of threats expected to rise*
  - *But number of Yellows should be fairly constant*
  - *Should be very few if any Reds*
  - *No Unknowns should be included*



# Threat Categories

- Project Management
  - *Affect project at system level*
    - Sys. Eng/Requirements
    - Launch Vehicle
    - System level test
    - Budget/Schedule
- Mission Operations
  - *Occur during Phase E*
    - Mission operations
    - Data analysis
- Science
  - *Science data processing system*
  - *Science requirements*

Threats by Mission, Milestone, and System



- Spacecraft
  - *Specific to spacecraft subsystems*
- Payload
  - *Affecting any of the scientific instruments on board the flight system*

# Milestone Analysis Summary – Threat Categories

- Trend

- *Increasing number of Project threats for each milestone*

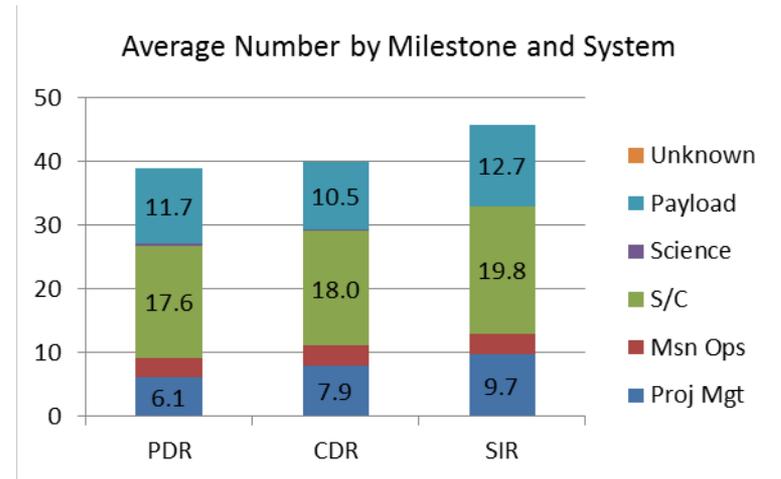
- General increase to Proj Mgt and Spacecraft threats across milestones

- *Average break out as follows:*

- 45% Spacecraft threats
- 30% Payload threats
- 20% Project Management threats
- Few Mission Operations threats
- Almost no Science threats

- Question

- *Given historical cost growth issues in Phase E, should there be more Mission Ops threats noted during development?*



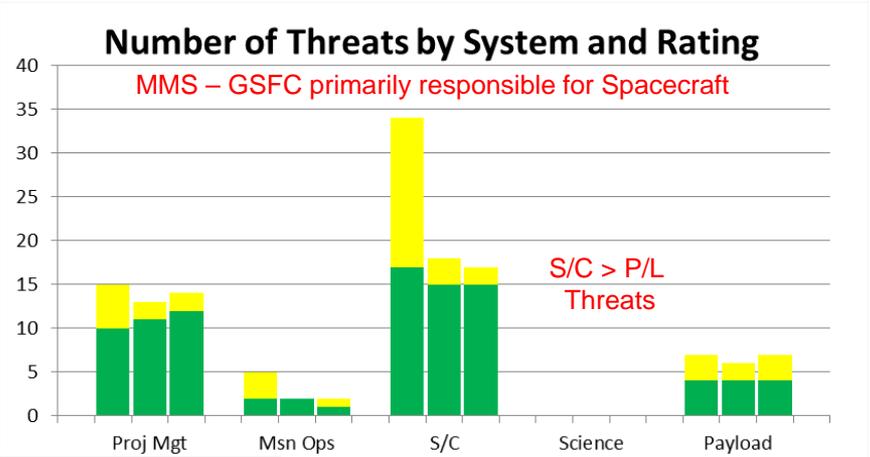
- Recommendations/Check List

- *Expect small increase to number of threats*

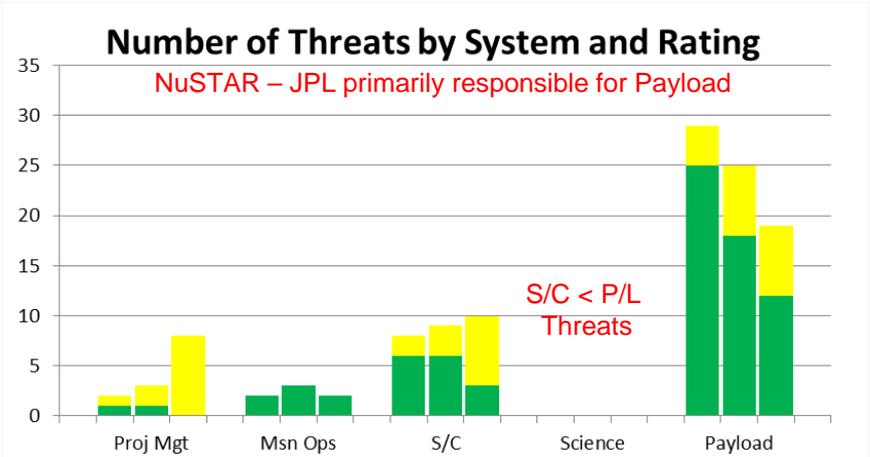
- Project
- Spacecraft
- Payload

- *Investigate reason for few number of Mission Ops threats*

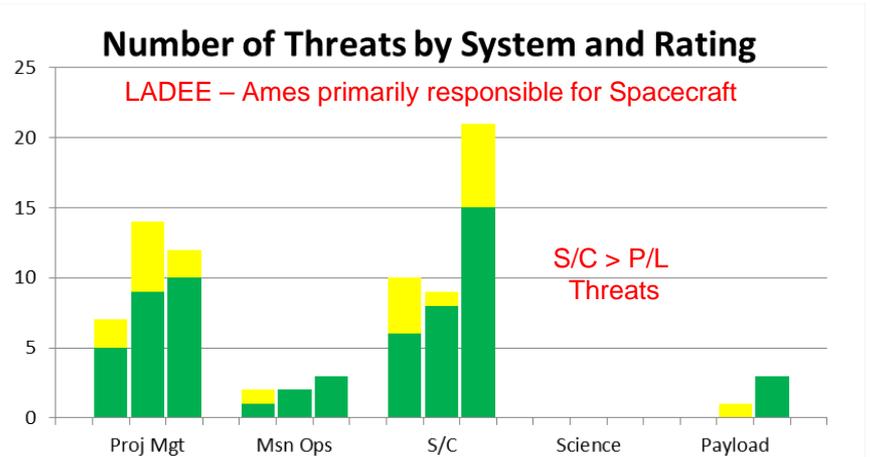
# Project Role Heavily Influences Risk Emphasis



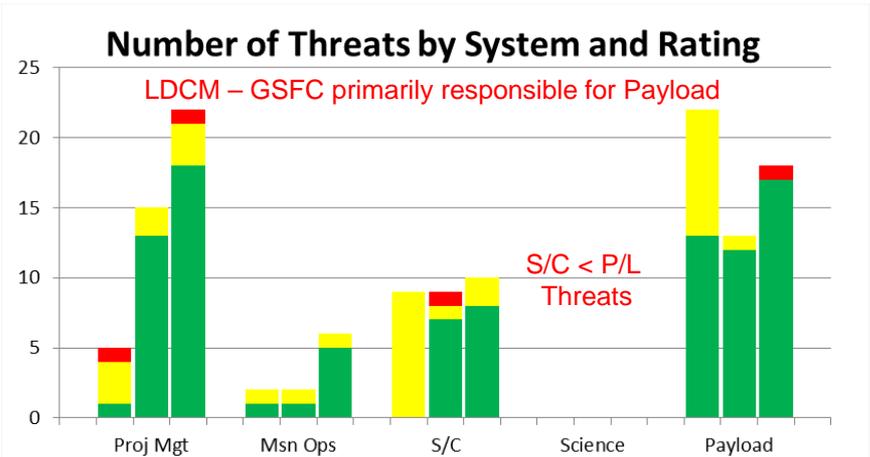
Each cluster represents PDR, CDR, then SIR



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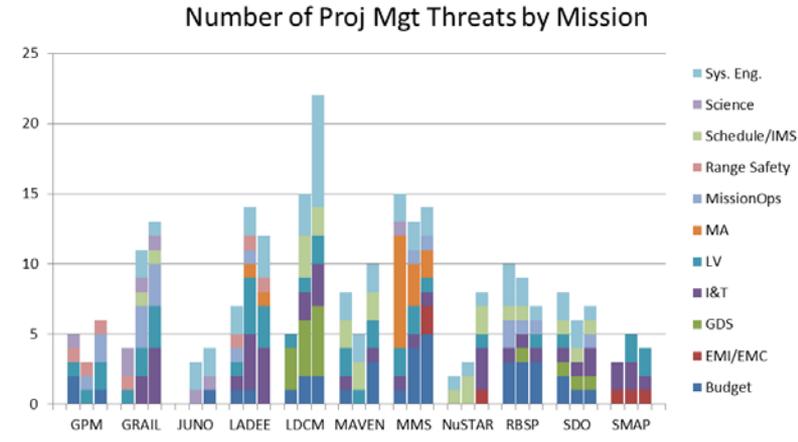
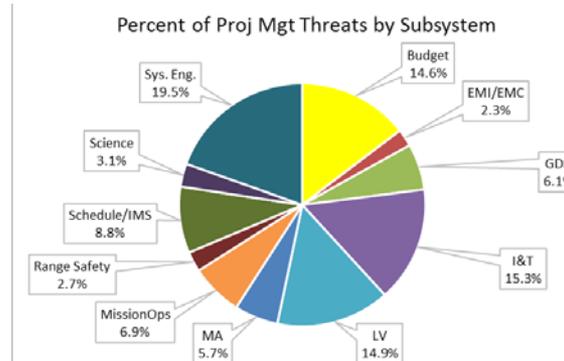


Each cluster represents PDR, CDR, then SIR

# Breakdown of Project Management Threats by Element

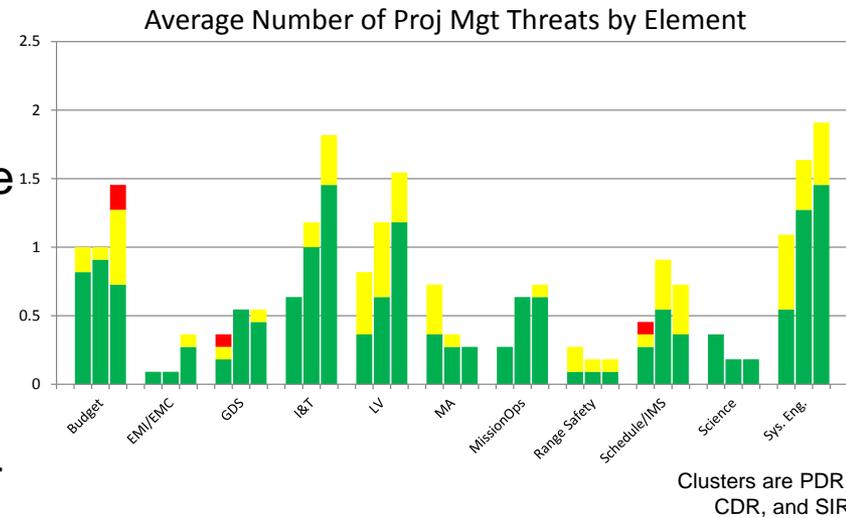
- Biggest contributors

- *Sys Eng.*
- *System I&T*
- *LV*
- *Budget*
- *Schedule*



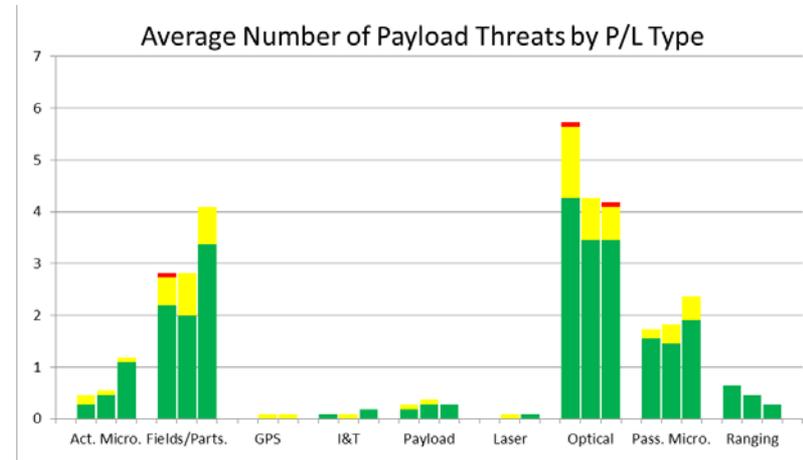
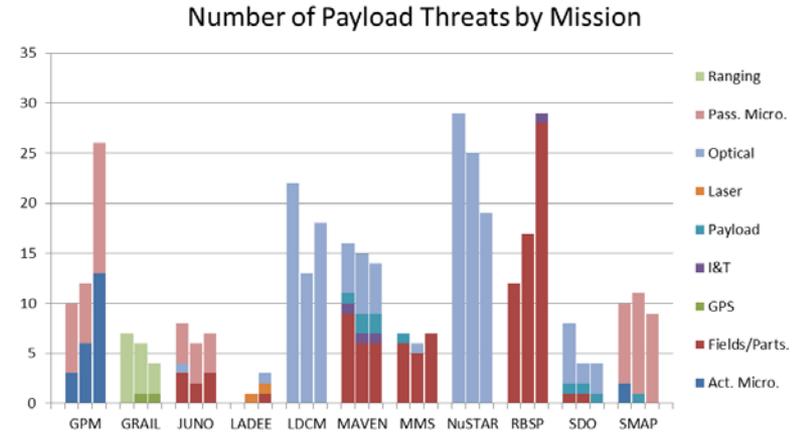
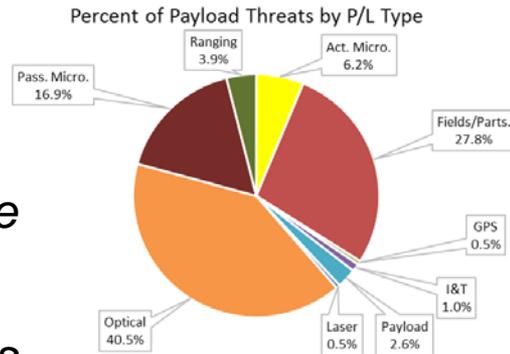
- Observations

- *Patterns*
  - Systems engineering plans & response to requirement changes can be numerous
  - Budget can contribute significantly to specific missions but not all
- *Top 5 elements account for about 80% of total*



# Breakdown of Payload Threats by Payload Type

- Biggest contributors (and only Red Threats)
  - *Optical*
  - *Fields/Particles*
  - *Passive Microwave*
- Observations
  - *Optical instruments*
    - Clear leader in number of threats at PDR and CDR
    - But threats are mostly worked off by SIR
  - *Top 3 payload types account for almost 85% of total*
- Number of threats are relatively small so summary isn't considered representative for extrapolation to larger set of missions

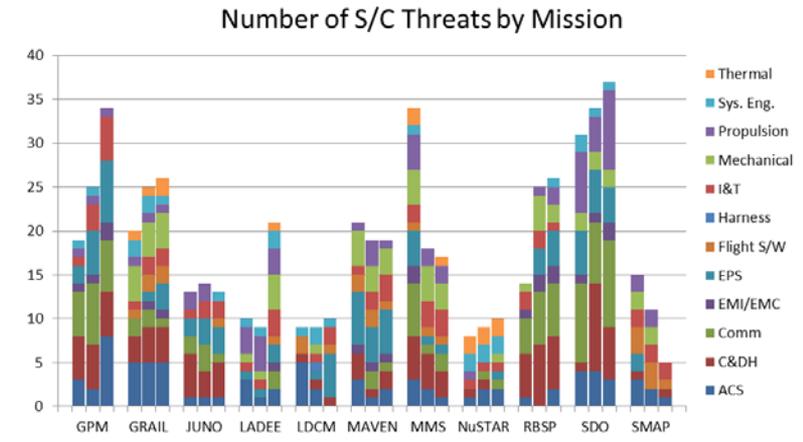
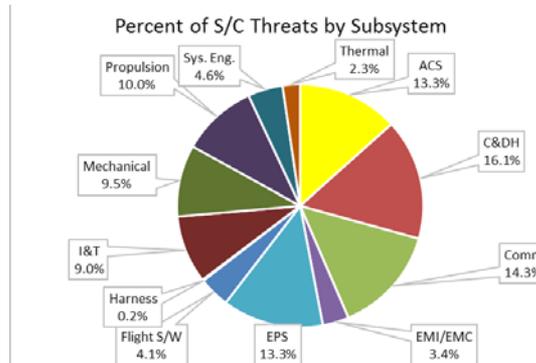


Clusters are PDR, CDR, and SIR

# Breakdown of Spacecraft Threats by Subsystem

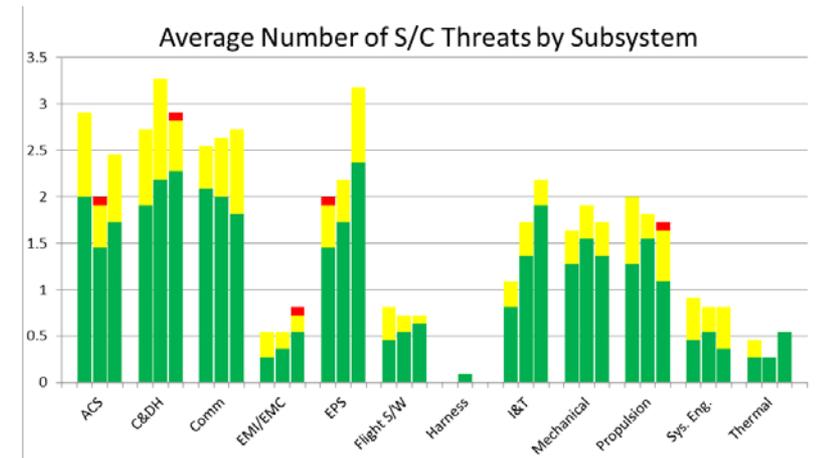
- Biggest contributors

- C&DH
- Comm
- ACS
- EPS
- Propulsion
- Struct/Mech
- I&T



- Observations

- Patterns
  - Few threats against Harness?
  - Steady rise in EPS and I&T
- Top 7 subsystems account for about 90% of total



Clusters are PDR, CDR, and SIR

# Spacecraft Subsystem Threat Change by Milestone

- Number of S/C Threats

- *I&T and EPS threats increase over time*

- I&T doubles from PDR to SIR
- EPS increases by 50% from PDR to SIR

- *Remaining number of subsystem threats stay relatively constant*

- Expected Value of S/C Threats

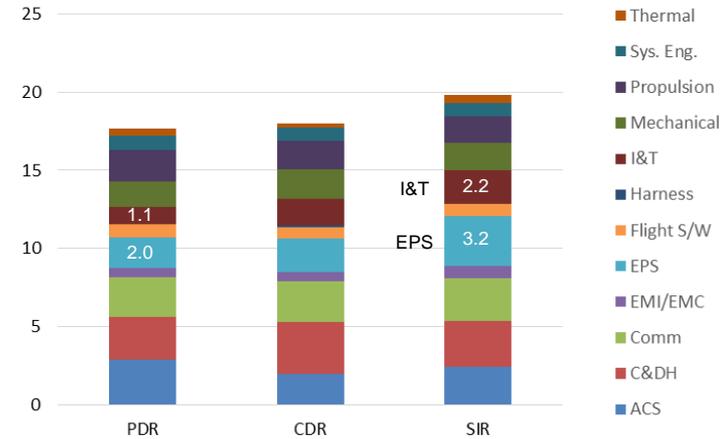
- *As expected, Total EV decreases by milestone*

- *Distribution at SIR is quite uniform among top 6 with over 80% of impact*

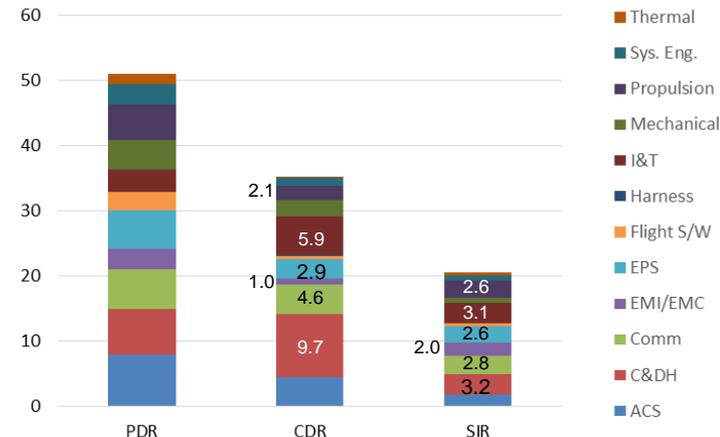
- *CDR to SIR*

- Propulsion (2.1 to 2.6) and EMI/EMC (1.0 to 2.0) subsystems increase
- C&DH declines but is largest (9.7 to 3.2)
- I&T declines but still large (5.9 to 3.1)
- EPS shows very small decline (2.9 to 2.6)

Number of Threats by Subsystem



EV(\$M) of Threats by Subsystem



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# Monetizing Risks - Process

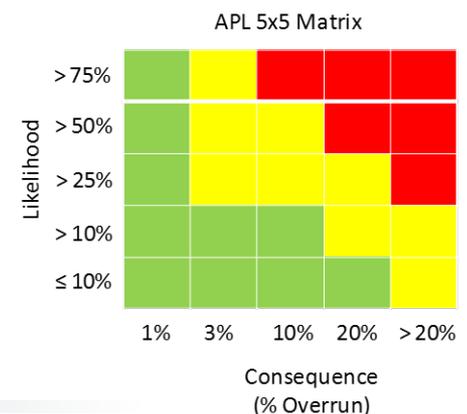
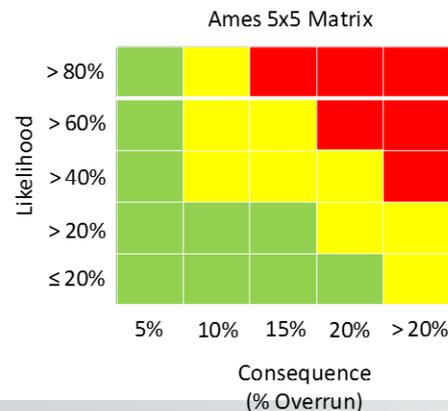
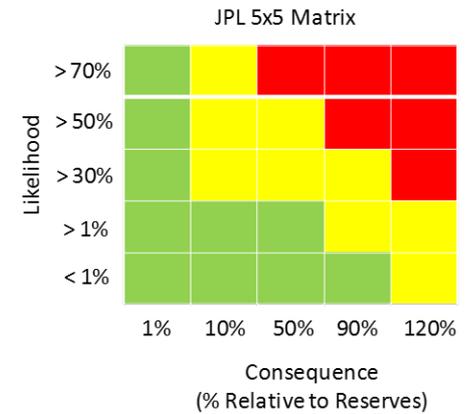
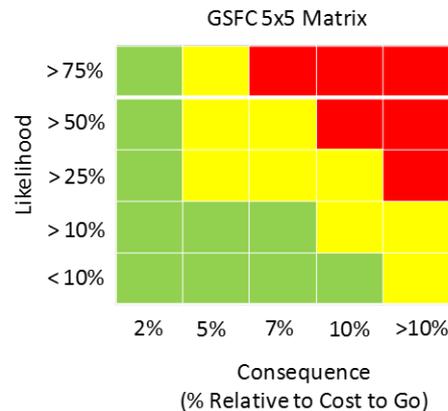
- Although most risk descriptions anticipate cost and schedule will be impacted, few risks actually quantify the cost/schedule impact
- Each Center has unique guidelines for cost/schedule impact placement in 5x5
  - Although guidelines exist, it is unclear that they are used when placing in 5x5
- Center 5x5 guidelines are used to determine a surrogate “threat value” for comparison

## • Rationale

- Monetizing the risks provides a better mechanism for comparing across projects than relying on number of threats

## • Data Required

- Likelihood and Consequence
- Cost
  - EAC, Cost to Go, Reserves

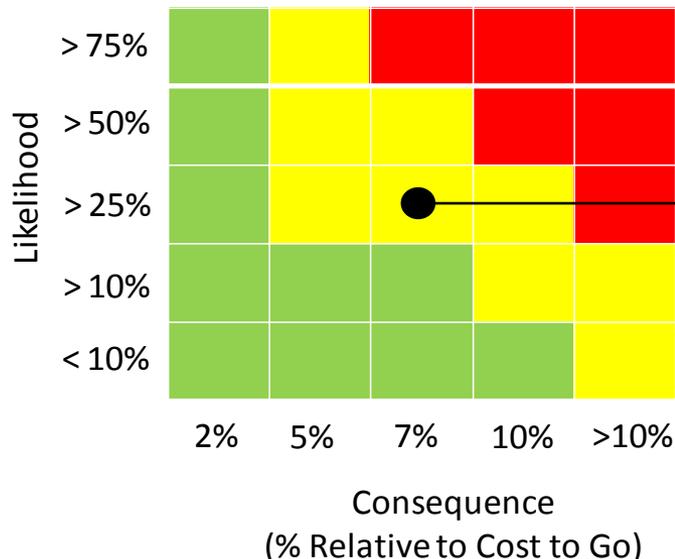


Each organization has a slightly different way to assess value of risks

# Monetization Example

- Uses Goddard 5x5 matrix for example
- Assume that:
  - *Likelihood (L)* is 3 so
    - Probability is 35% (i.e. > 25% but less than 50% in matrix)
  - *Consequence (C)* is 3 so
    - Percent relative to cost to go is 6% (i.e. > 5% but less than 7% in matrix)
  - *Cost to go (CTG)* is \$100M

GSFC 5x5 Matrix

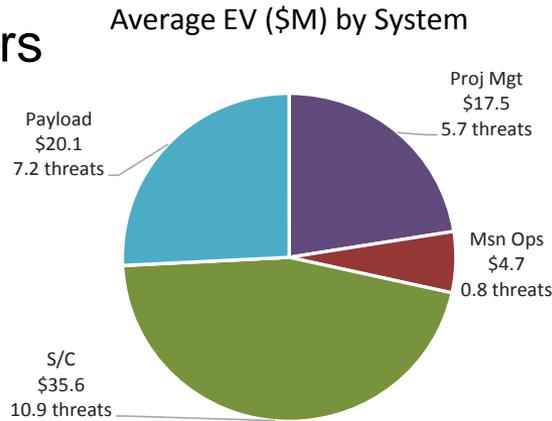


- Calculated threat value  
 $= L * C * CTG$   
 $= 35\% * 6\% * \$100M$   
 $= \$2.1M \text{ Expected Value}$

# Expected Value by System

- Biggest contributors

- *Spacecraft*
- *Payload*
- *Project*



- Observations

- *EV by Mission*

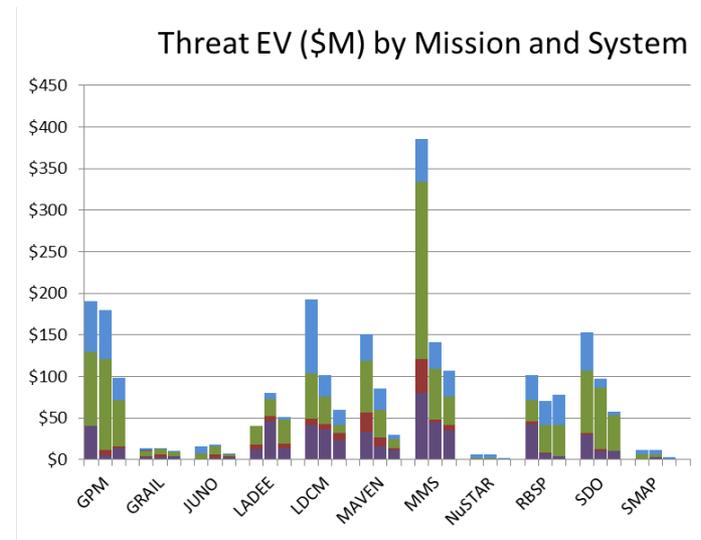
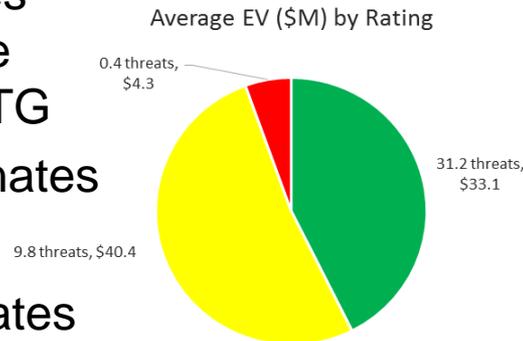
- Usually decreases at each milestone given reduced CTG

- Spacecraft dominates

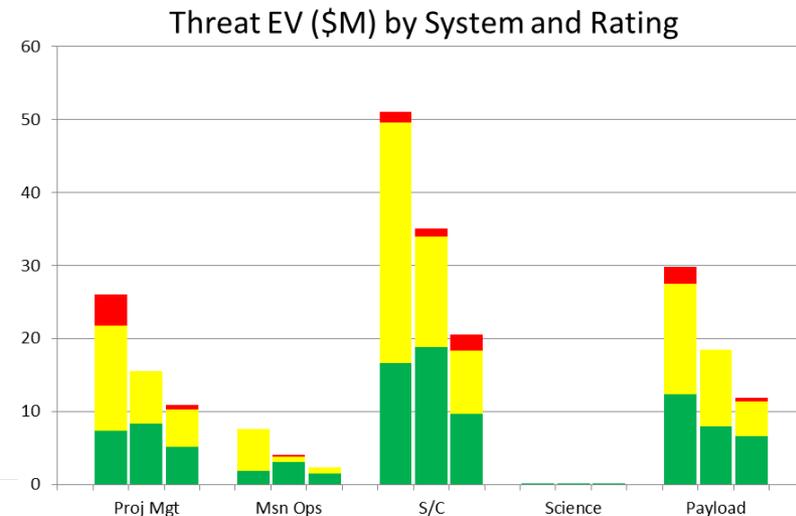
- *EV by Rating*

- Yellow predominates

- Green outweighs Red in total due to combined effect

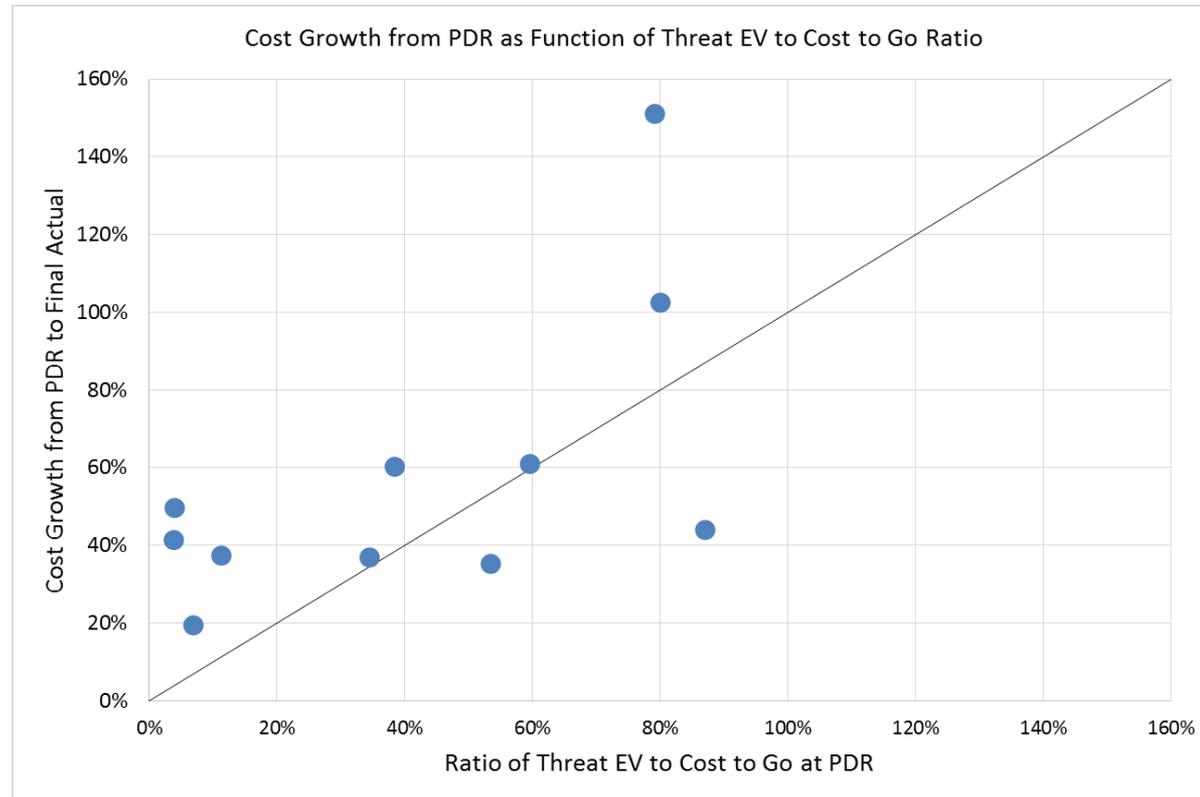


Clusters are PDR, CDR, and SIR



# Monetizing Risks – EV and Cost To Go Ratio

- Graphs show plot of actual growth on cost to go vs. expected value of threats on cost to go using Center 5x5 quantification
- If expected value of threat is equal to actual growth, then project would be on the diagonal line of unity
- As can be seen, majority of project are above diagonal indicating that expected value of threats is less than the actual cost growth
- This would imply that project threat assessments are typically understated which is consistent with other observations that show limited contribution of discrete threats to JCL

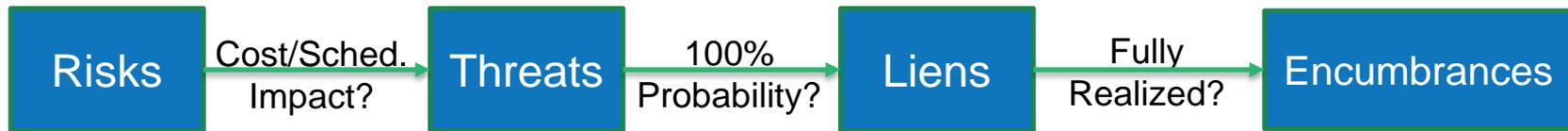


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# MAVEN Deep Dive

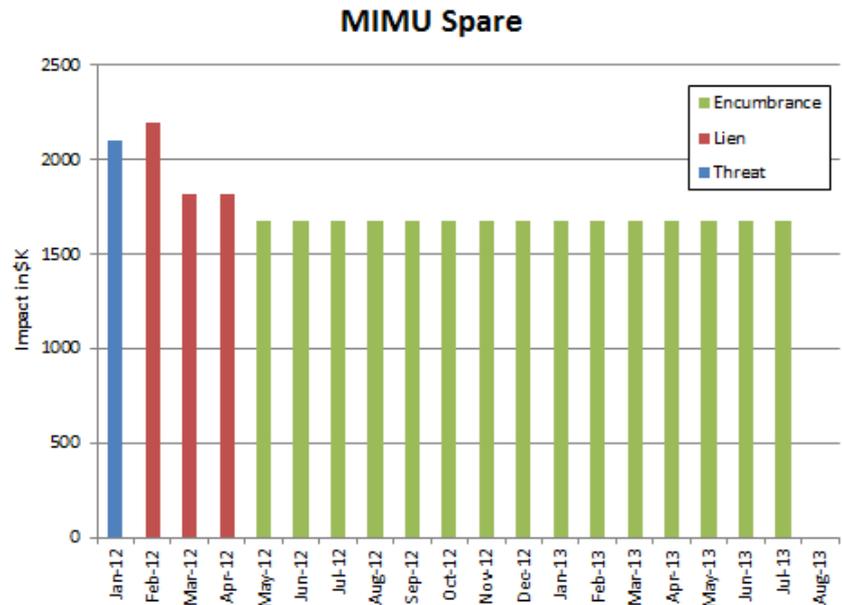
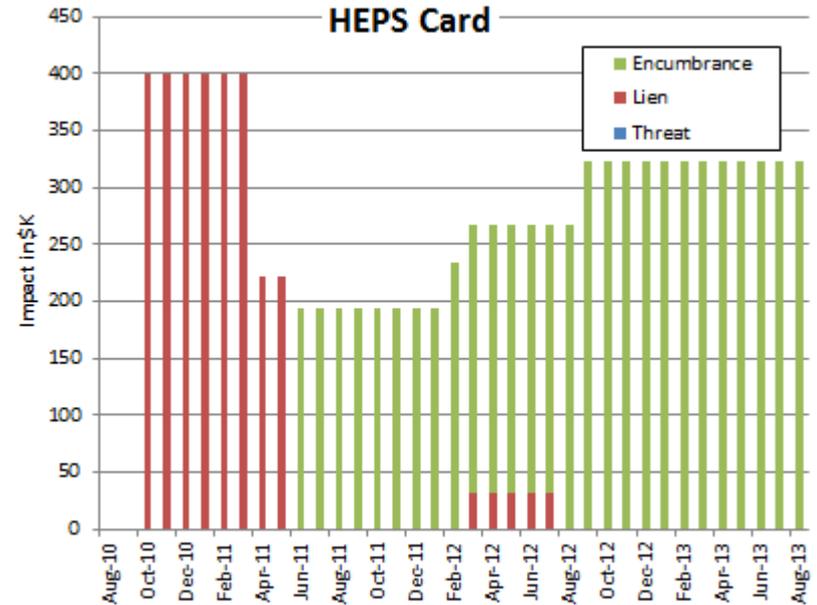
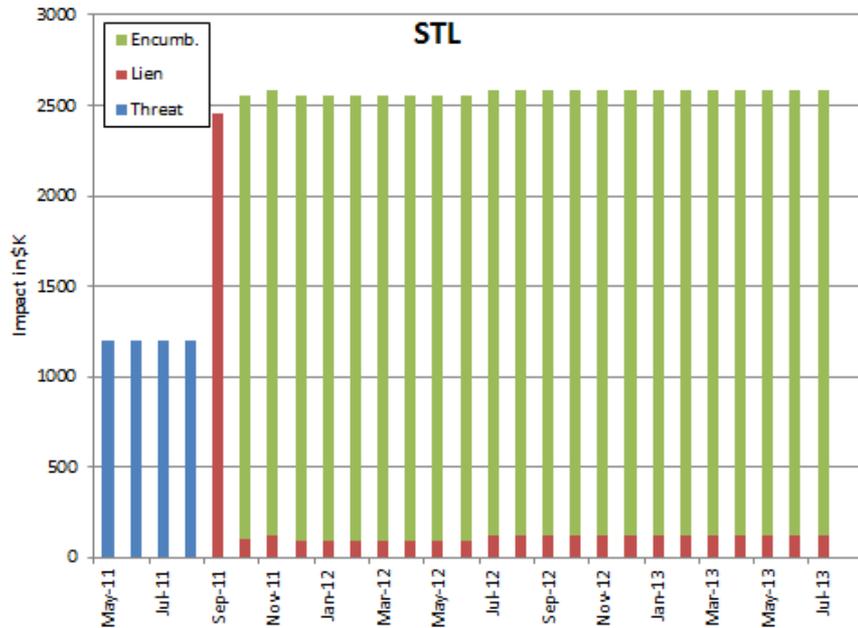
- Using MAVEN to examine the flow from Risks to Threats to Liens to Encumbrances (based on Goddard Procedural Requirement 7120.4D)
  - *Are there patterns we can learn from or leverage?*
  - *Does MAVEN exhibit some best practices*



- Collected risks using MSRs from May 2011 through October 2013
- Excellent pattern for monthly recording of
  - *Threats*
  - *Liens and Encumbrances*
- Project explicitly monetizes Threats with cost and schedule impacts distributed by FY

# MAVEN Deep Dive Examples

- Number of examples we can trace all the way from threat to encumbrance limited by
  - *Inconsistencies*
  - *Lack of detail*
  - *Change to Threat IDs*
- First set of 'good' data is May 2011



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# Checklist for SRB/JCL Process

- Full list of active project-level risks at each milestone should be on the order of 30 to 50 risks
- All risks with cost/schedule impacts should have a quantified dollar or duration value to facilitate input into JCL process
  - *Green risks, when taken as a whole, contribute substantially to the overall expected value*
- Distribution of risks should be split on the order of 45% spacecraft, 30% instruments, 20% project management, 5% other
- Project risks typically focus on element of primary responsibility of Center so look closely at elements for which Center is not primarily responsible for
- Number of threats should increase over time, especially spacecraft integration and test issues and, secondarily, electrical power subsystem
- Mission ops threats are limited and, given recent growth in Phase E, may need additional focus

# Recommendations

- Full list of active project-level risks at each milestone
  - *A dump from the Risk-Tracking system*
  - *Excel-compatible*
  - *All project-level risks should be rolled up into a single source*
- Risks need a unique project-level ID that is immutable
  - *Clear and traceable process required to manage risks that split or join*
  - *Liens and Encumbrances should have a link back to underlying risks*
- Development risks need to quantify cost/schedule impact (i.e. Threat)
- Standardize Risk/Threat/Lien/Encumbrance progression
  - *Consequence expressed in dollars rather than index*
  - *Consequence by FY if possible*
  - *Fix on standard terminology*
- Develop NASA guidance on 5x5 cost/schedule likelihood and consequence

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- Accomplishments
  - *Collected and summarizes detailed risk lists for NASA missions from milestones taken from PDR, CDR and SIR*
  - *Developed database of risk lists, categorize rating/type of risks at each milestone and other statistics*
  - *Developed checklist and recommendations for developing threat list for future JCL analysis*
- Recommendations
  - *Require a full, clearly named, project-level risk list at each milestone with consistent risk ID naming/tracking*
  - *Require projects to quantify cost/schedule impact of risks*
  - *Require consistent tracking from risks to threats to liens to encumbrances*
  - *Provide NASA-level guidance of 5x5 cost/schedule impact quantification*
  - *Provide risk database and guidelines to SRB & JCL teams*