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

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# Outline

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



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# Study Goal and Approach

- Goal
  - *Create a defendable, 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*



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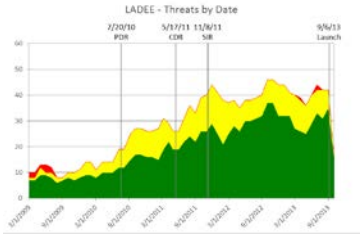
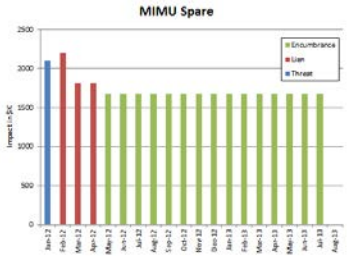
# Process Overview

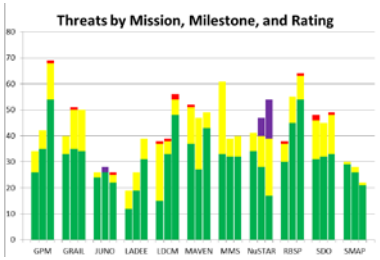
Data Collection & Assessment

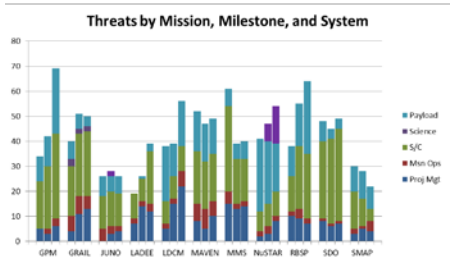
| Mission | Program | Center | Destinati | Theme | Num Threa |
|---|---|---|---|---|---|
| GPM | Earth Sys. | GSFC | Earth | Earth Science | 145 |
| GRAIL | Discovery | JPL | Moon | Planetary | 141 |
| JUNO | New Frontie | JPL | Jupiter | Planetary | 80 |
| LADEE | Lunar Quest | ARC | Moon | Planetary | 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 |

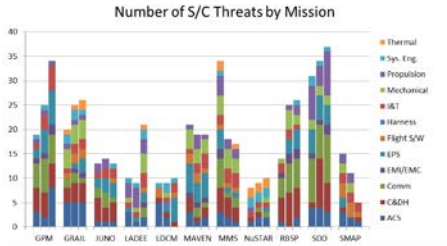


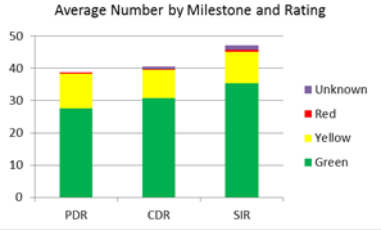

Risk/Threat Categorization

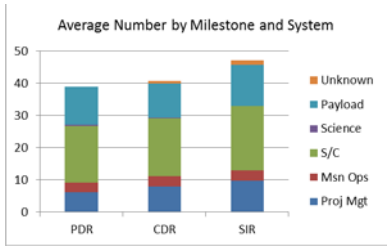


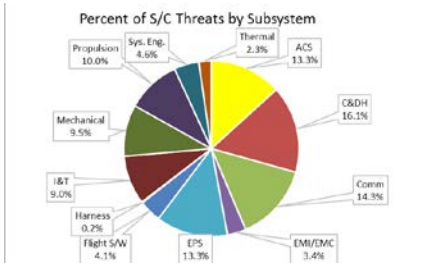



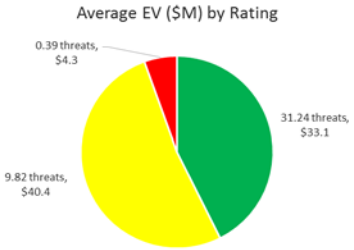

Threat Averages & Distributions

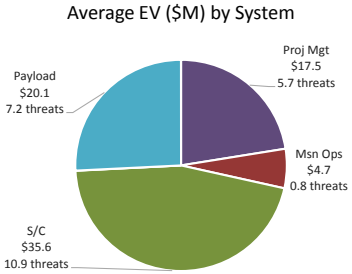


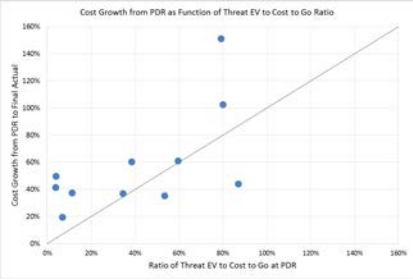




Threat Quantification



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# 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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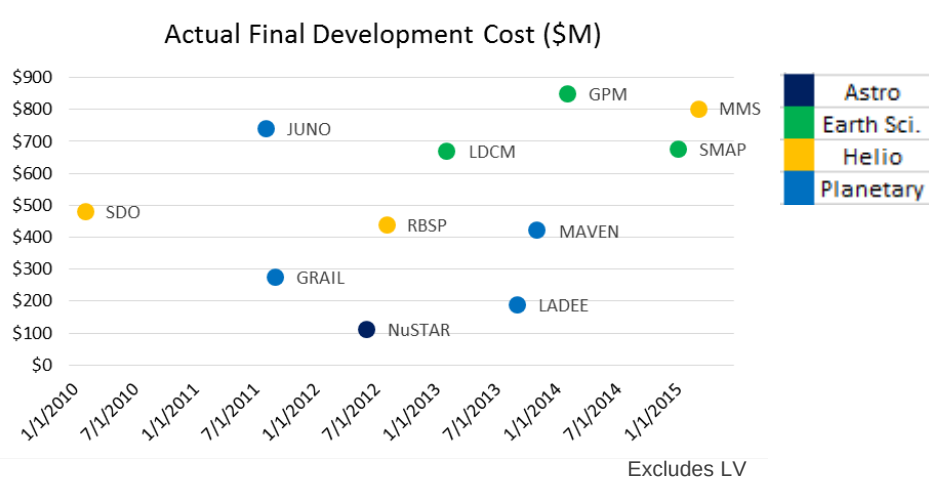
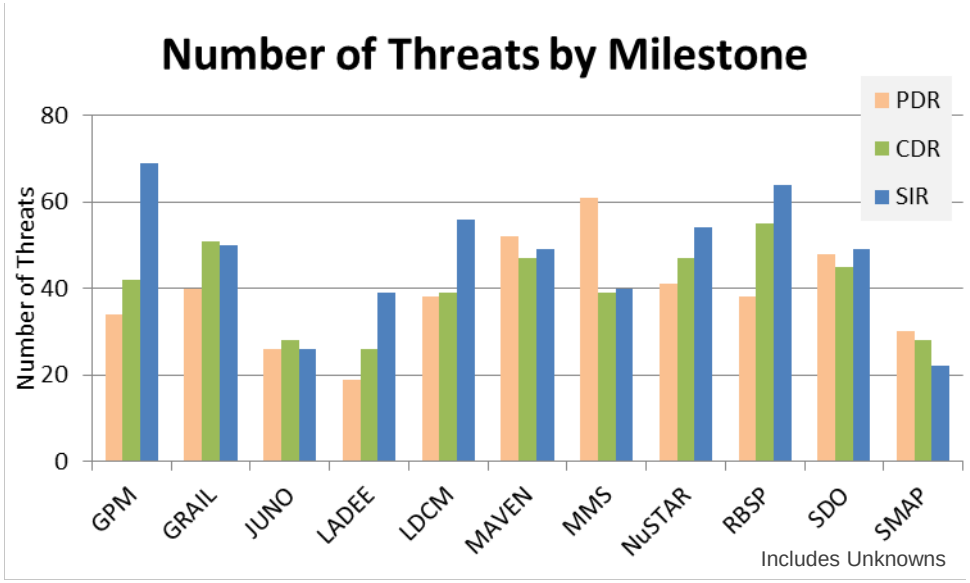
# Mission Set

- 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



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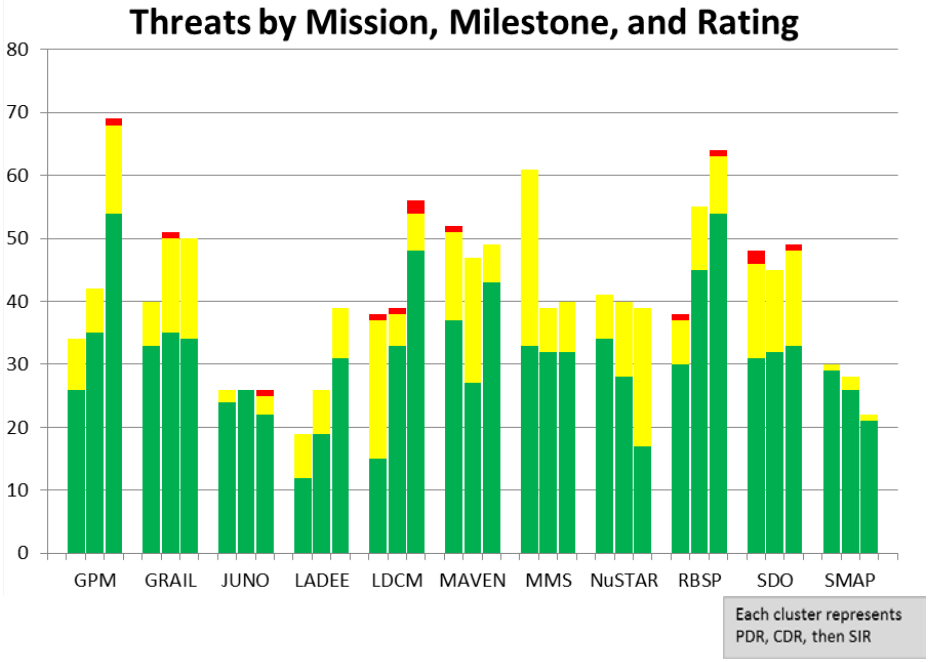
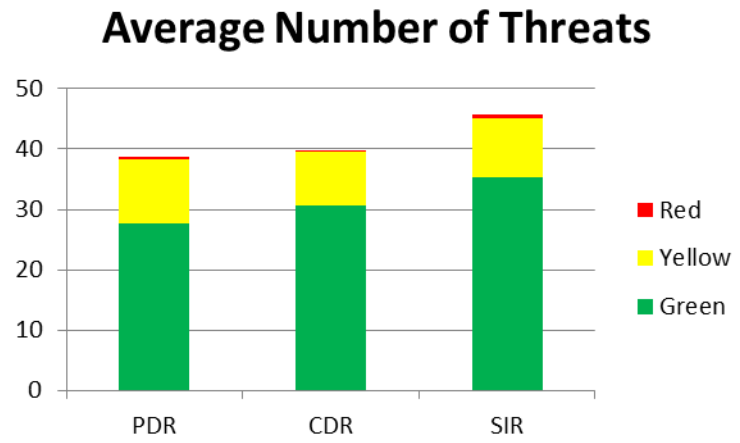
# Milestone Analysis Summary – Threat Rating

- 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*



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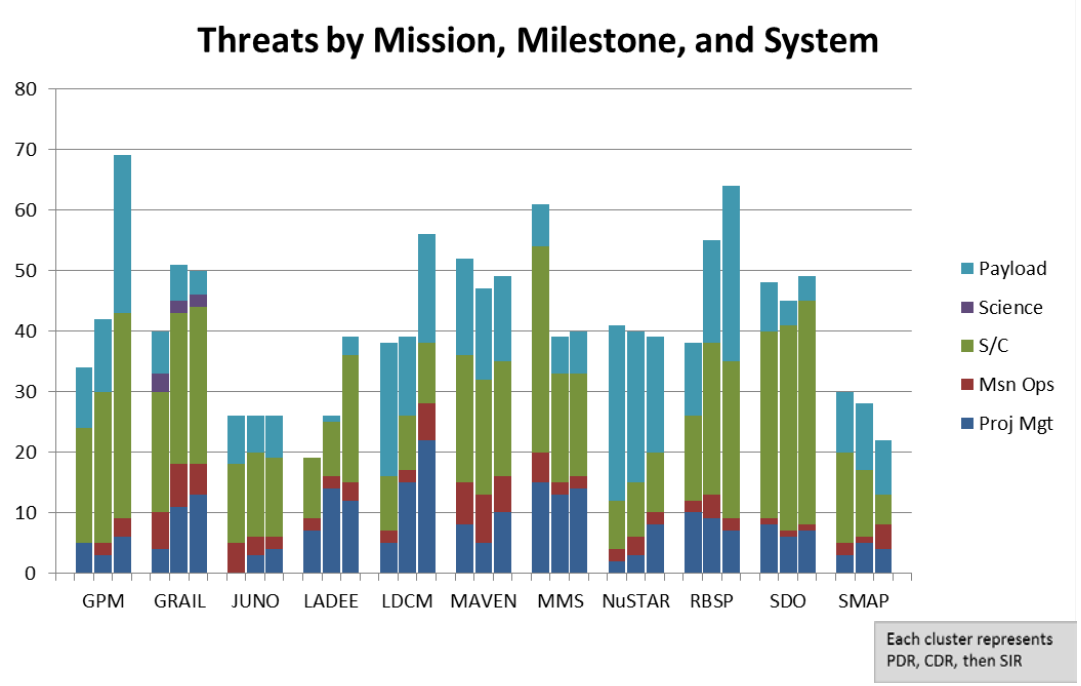
# Threat Categories

- 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*




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



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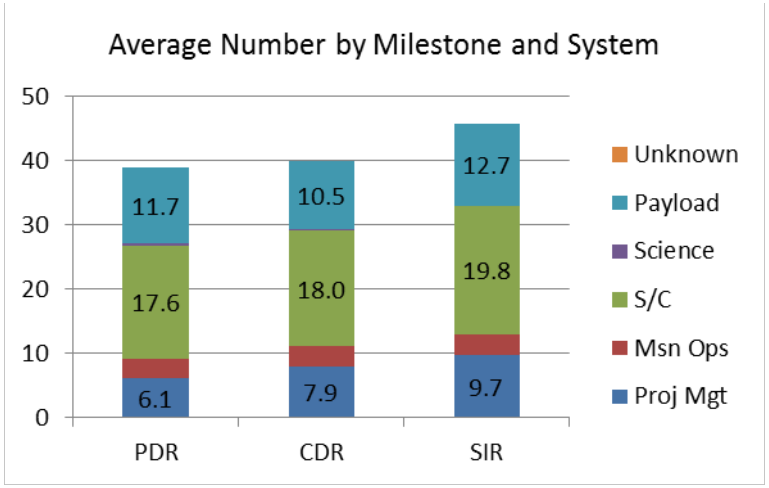
# Milestone Analysis Summary – Threat Categories

- 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*



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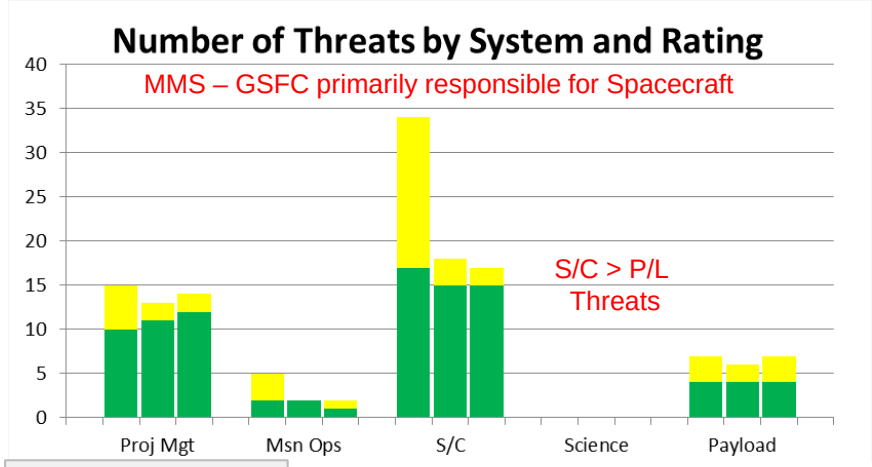
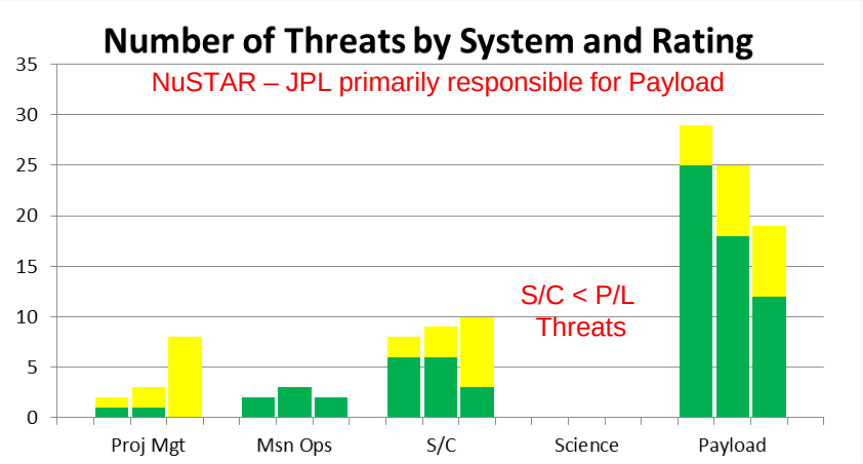
# Project Role Heavily Influences Risk Emphasis




Each cluster represents PDR, CDR, then SIR

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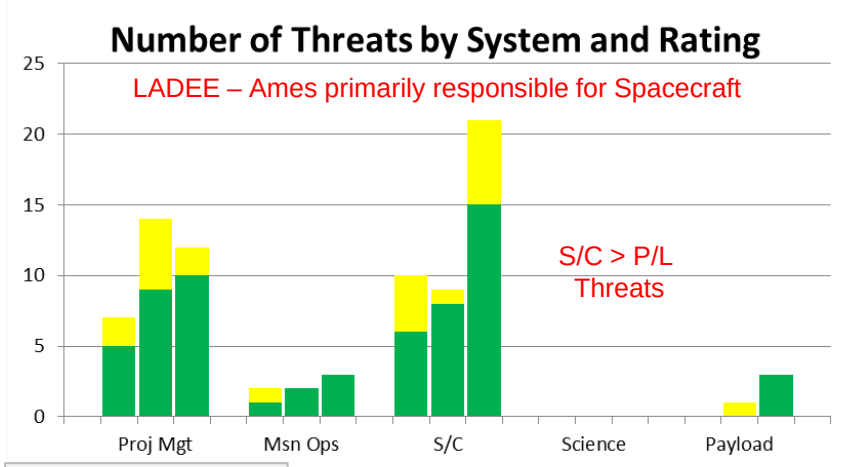


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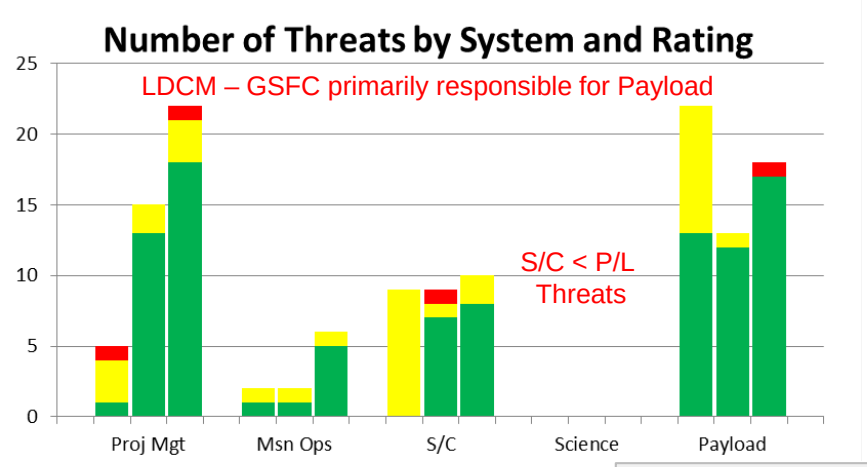


Each cluster represents PDR, CDR, then SIR



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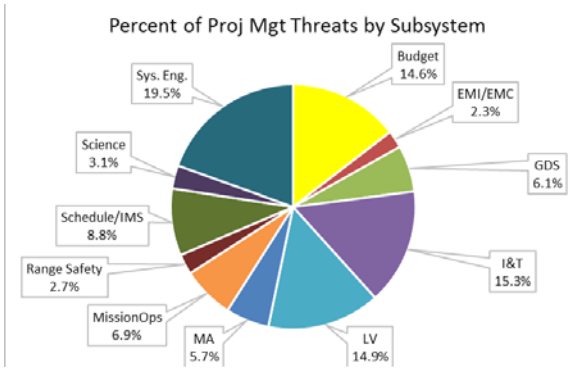
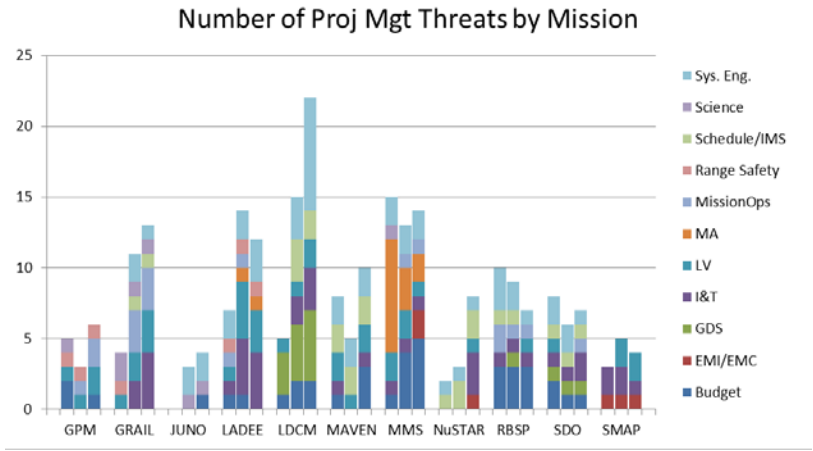
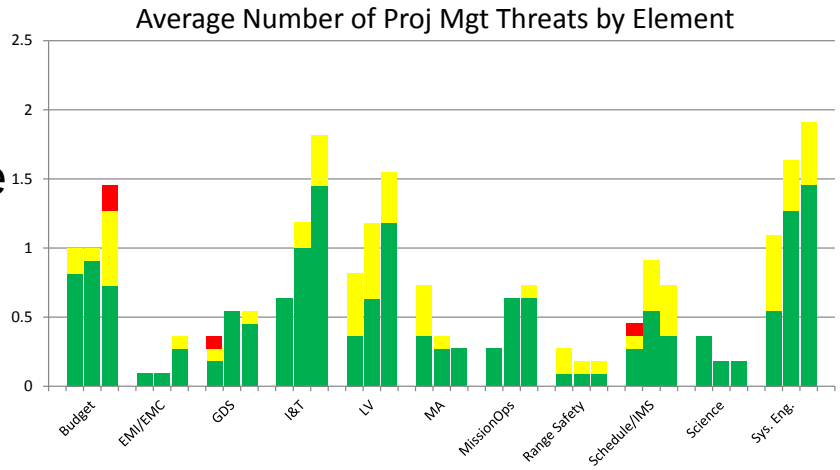
# Breakdown of Project Management Threats by Element

- 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*




Clusters are PDR, CDR, and SIR



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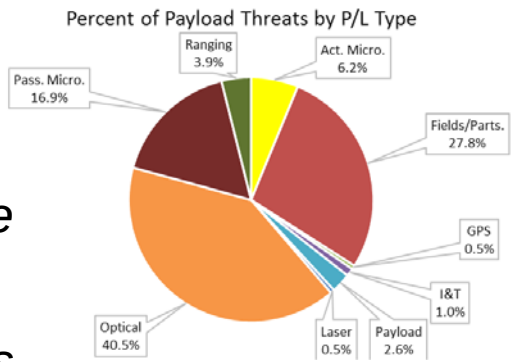
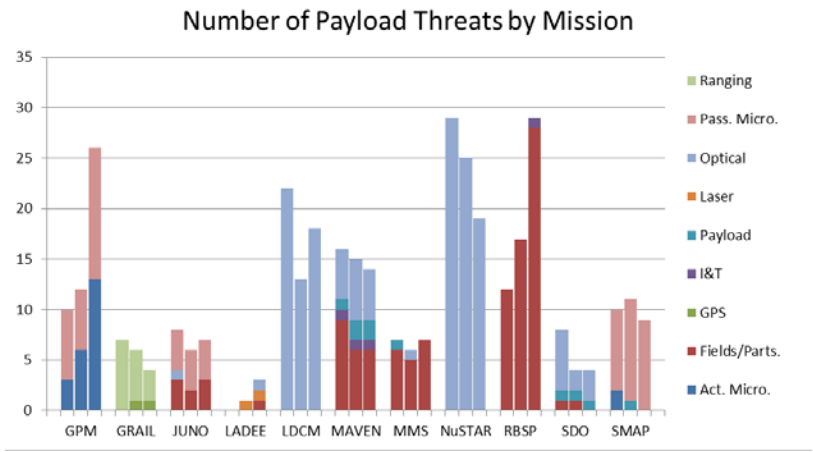
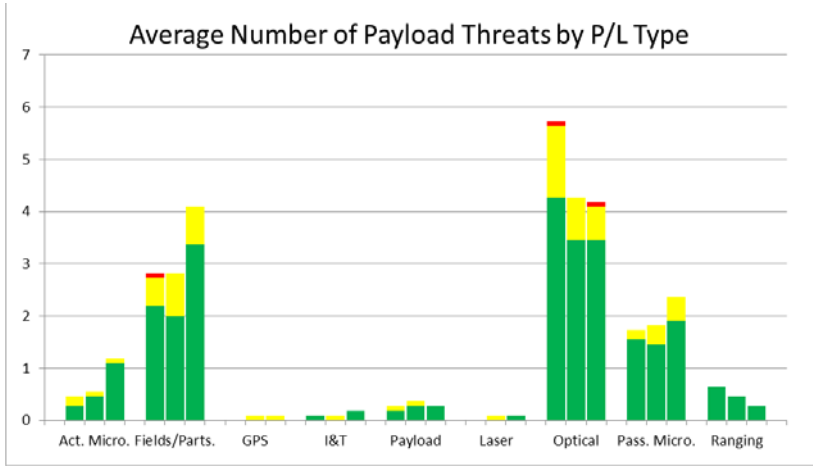
# Breakdown of Payload Threats by Payload Type

- 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



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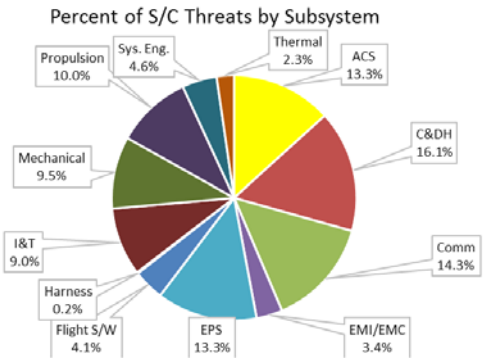
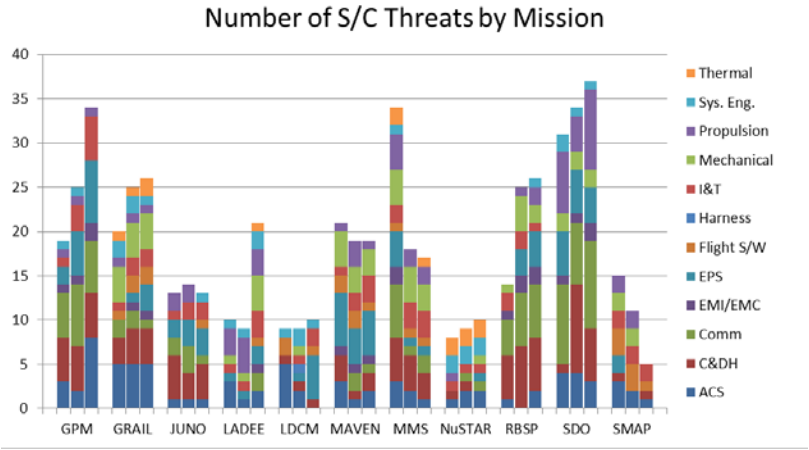
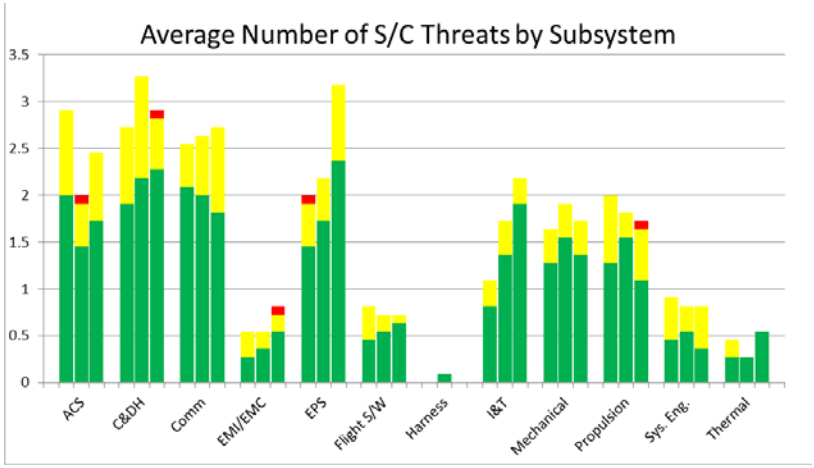
# Breakdown of Spacecraft Threats by Subsystem

- 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



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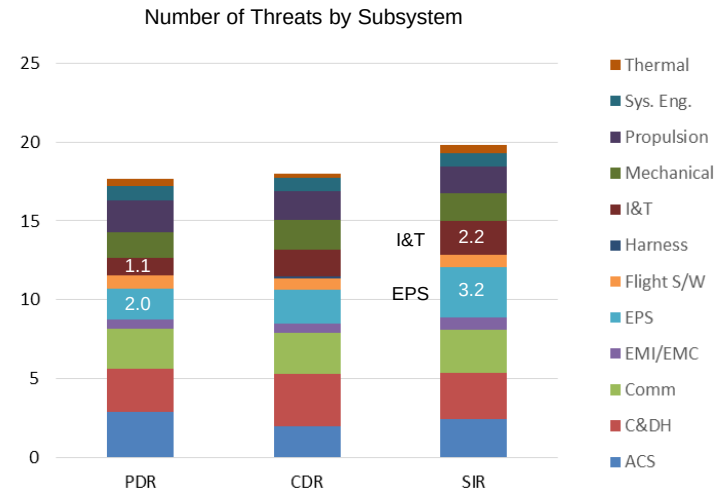
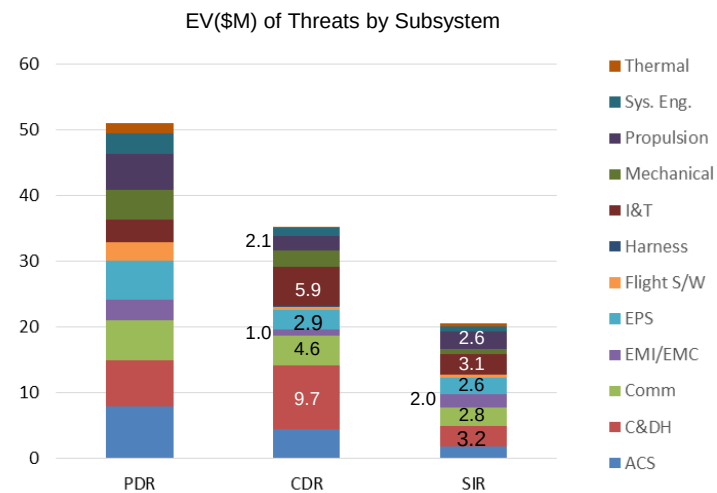
# Spacecraft Subsystem Threat Change by Milestone

- 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)



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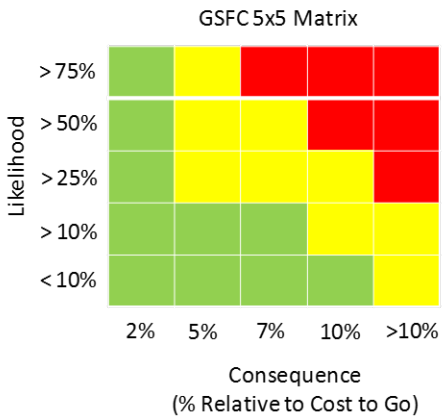
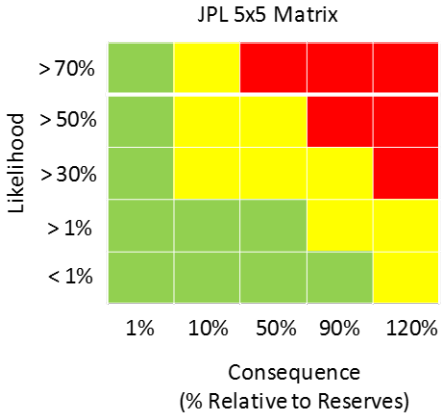
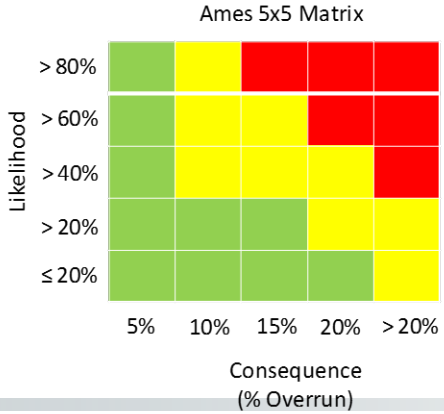
# Monetizing Risks - Process

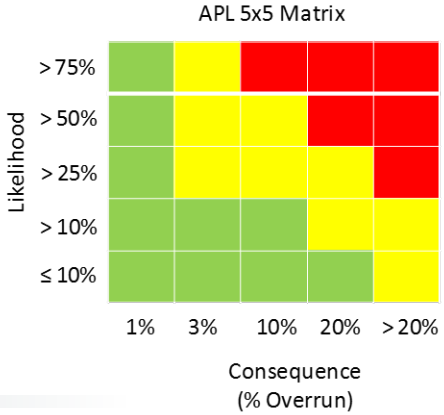
- Although most risk descriptions anticipate cost and schedule will be impacted, few risks actually quantify the cost/schedule impact
- Each Center has unique guidelines for cost/schedule impact placement in 5x5
  - *Although guidelines exist, it is unclear that they are used when placing in 5x5*
- Center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



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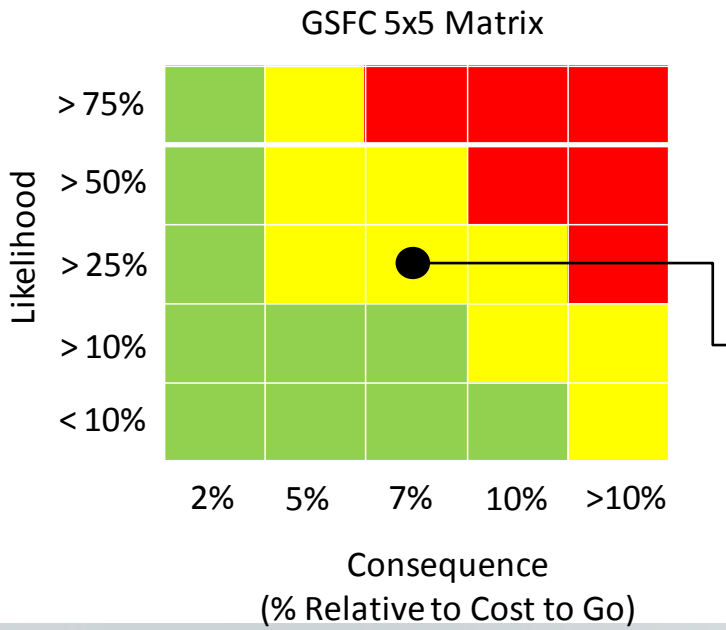
# Monetization Example

- 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*




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



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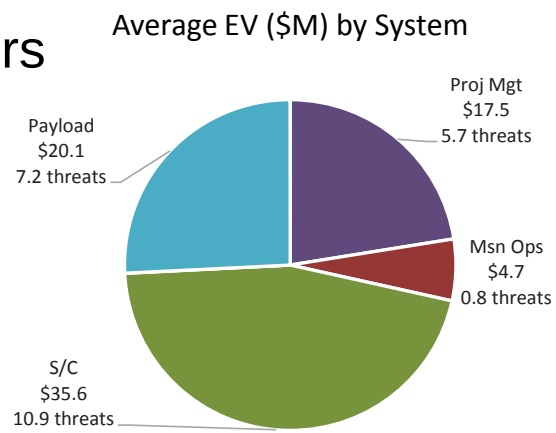
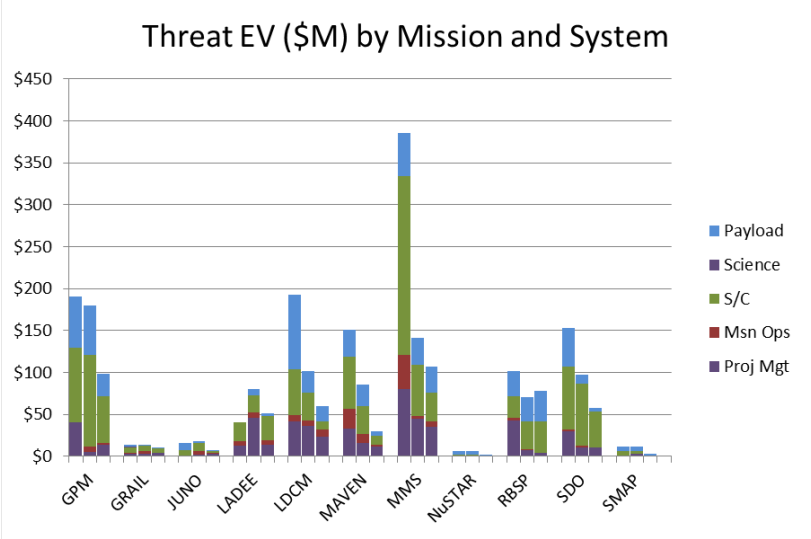
# Expected Value by System

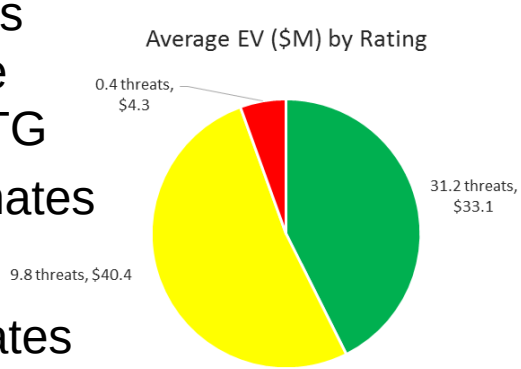
- Biggest contributors
  - *Spacecraft*
  - *Payload*
  - *Project*

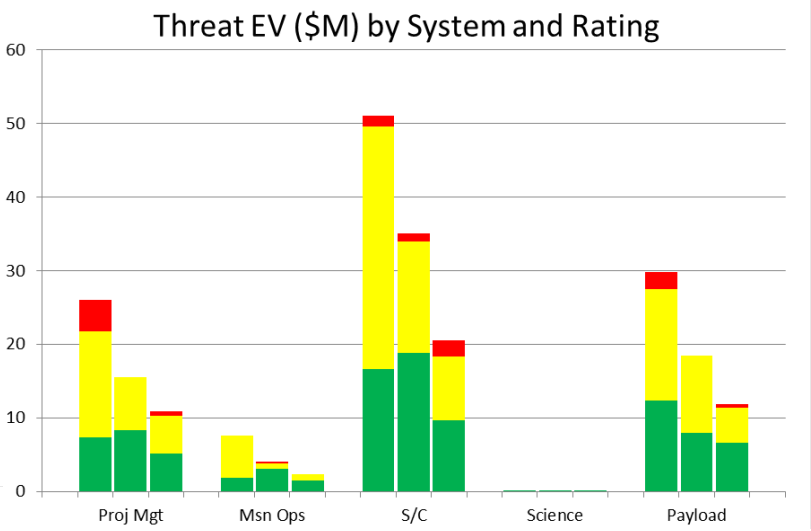



Clusters are PDR, CDR, and SIR

- 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



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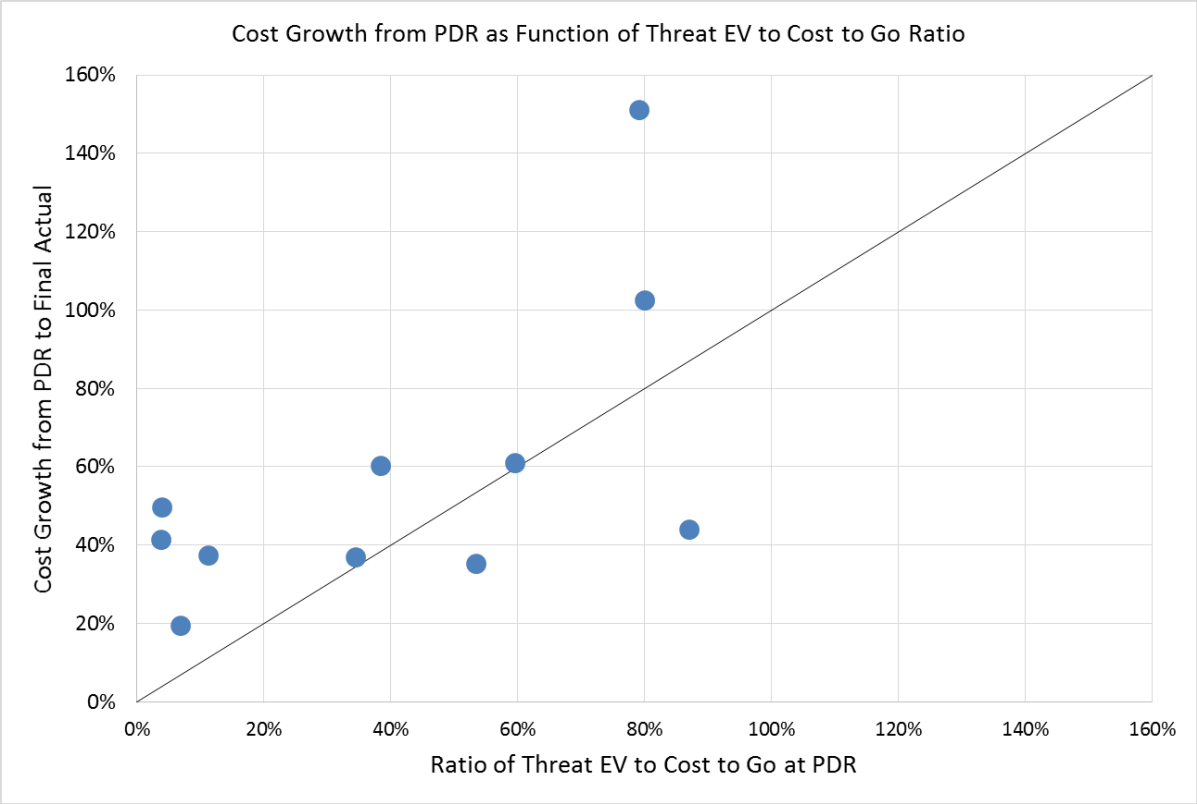
# Monetizing Risks – EV and Cost To Go Ratio

- 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 scan 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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# Outline

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



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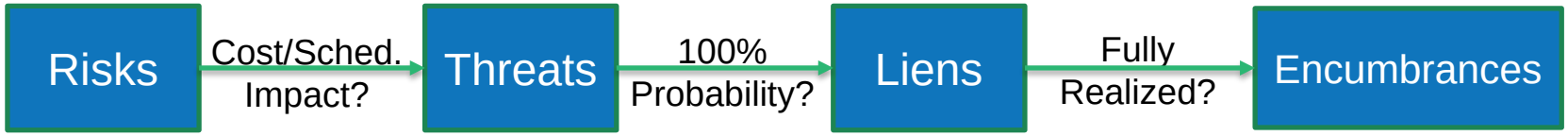
# MAVEN Deep Dive

- 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



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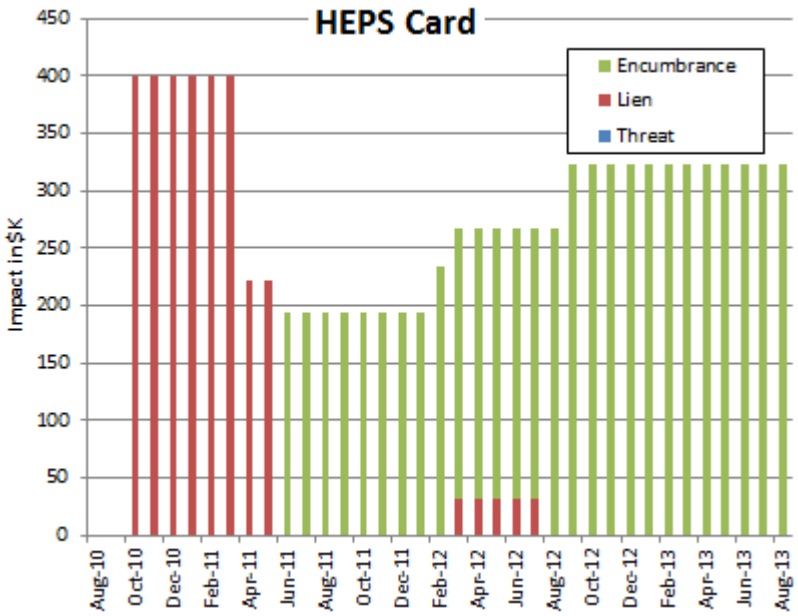
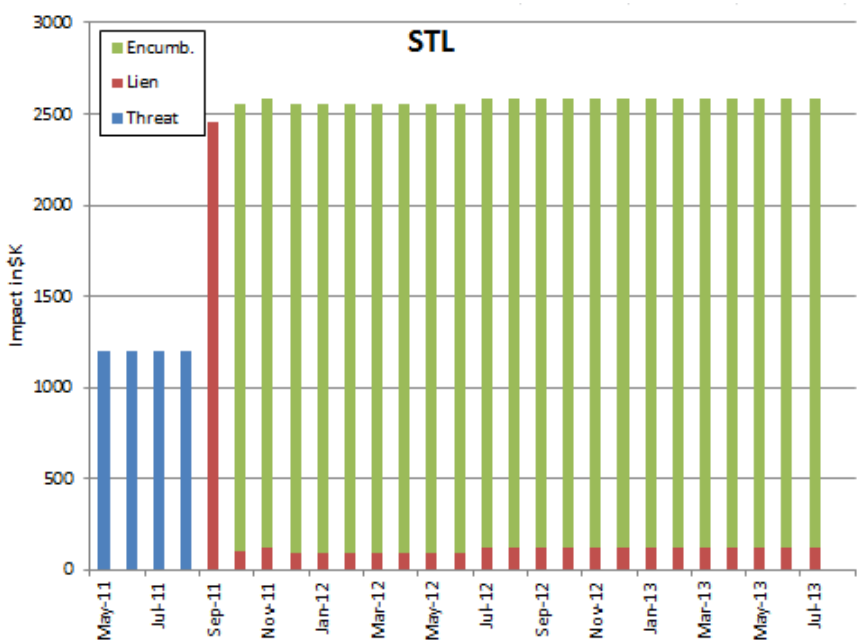
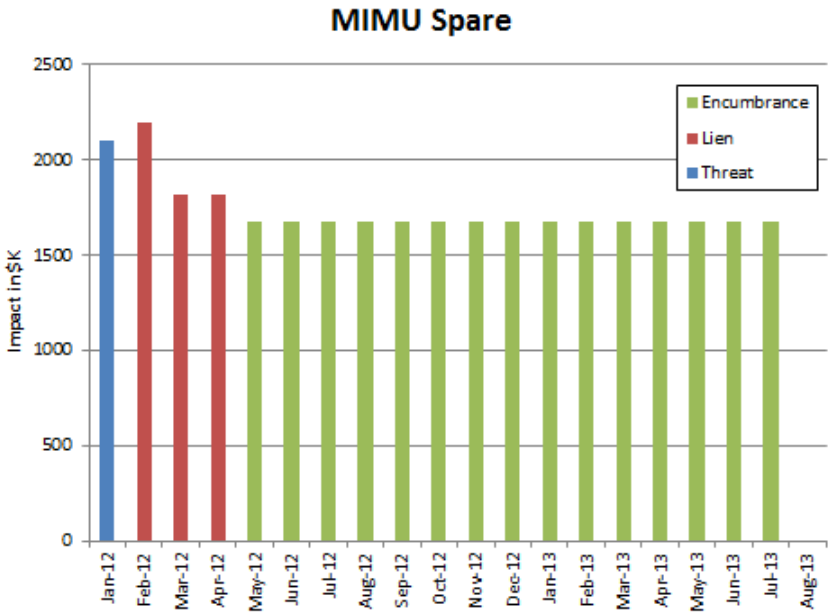
# MAVEN Deep Dive Examples

- 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



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# 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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# Summary

- 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*



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