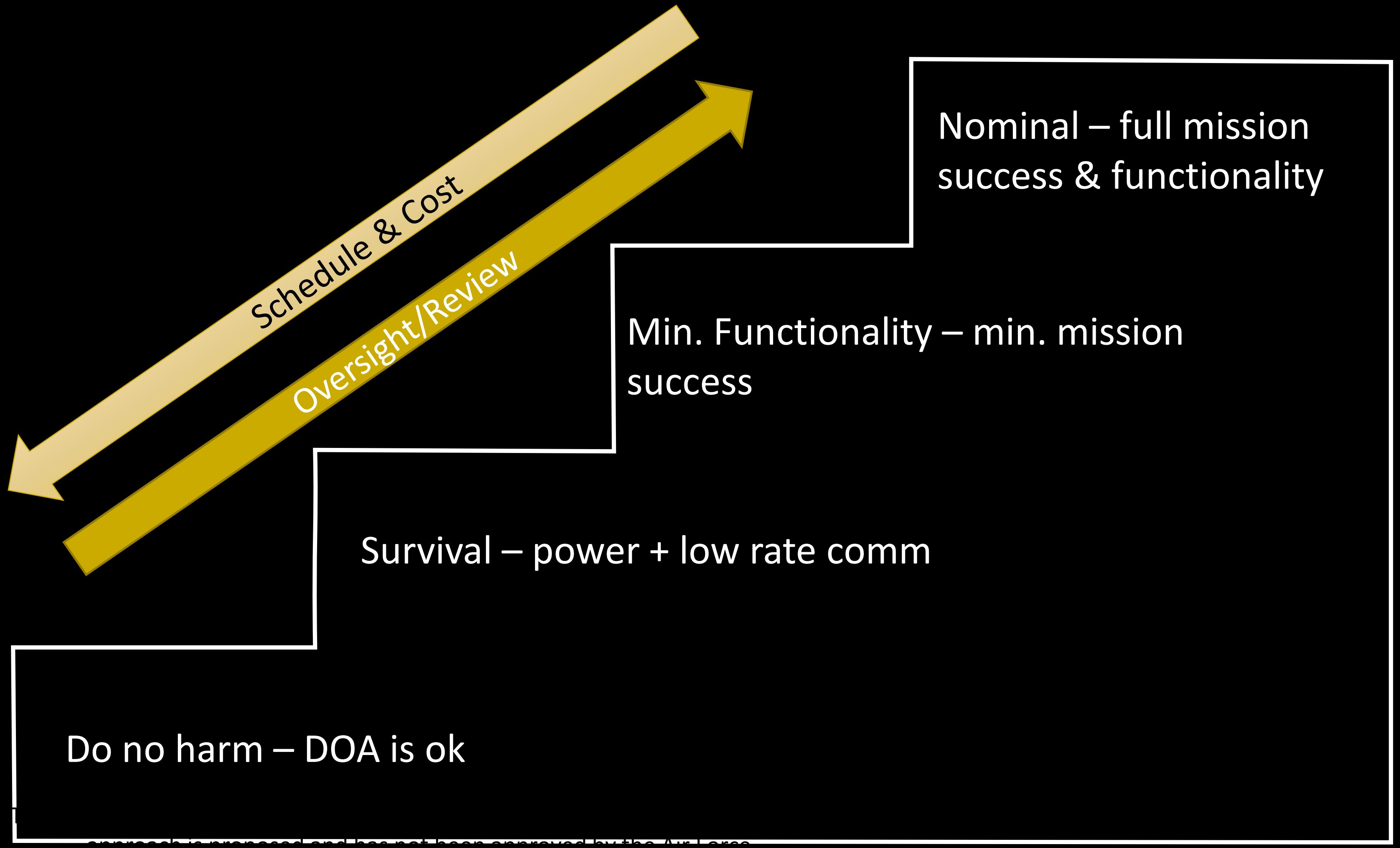
22%

Constraint – Driven Mission Assurance Taxonomy



SMALL SATELLITE PORTFOLIO
AIR FORCE RESEARCH LABORATORY

Defining a New Mission Assurance Philosophy for Small Satellites

Dr. Lee Jasper – SDL

Dr. Lauren Hunt, Dr. David Voss, Ms. Charlene Jacka – AFRL

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SmallSat Conference 4 August 2018

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WHY DOES MISSION ASSURANCE EXIST?

SmallSat Mission Assurance Realities

1. Constraint-driven missions are the most common

SmallSat Mission Assurance Realities

1. Constraint-driven missions are the most common

CONSTRAINT DRIVEN

Mission scope fits into capabilities and complexity available given technical, programmatic and oversight needs

REQUIREMENTS DRIVEN

Mission scope is static and resources applied to achieve that mission

Fit within the "box" given to you ⟷ Build your own box

SmallSat Mission Assurance Realities

1. Constraint-driven missions are the most common
2. Class D mission assurance practices are significantly modified or ignored
3. Class D overhead can dilute the full potential contribution of small satellites

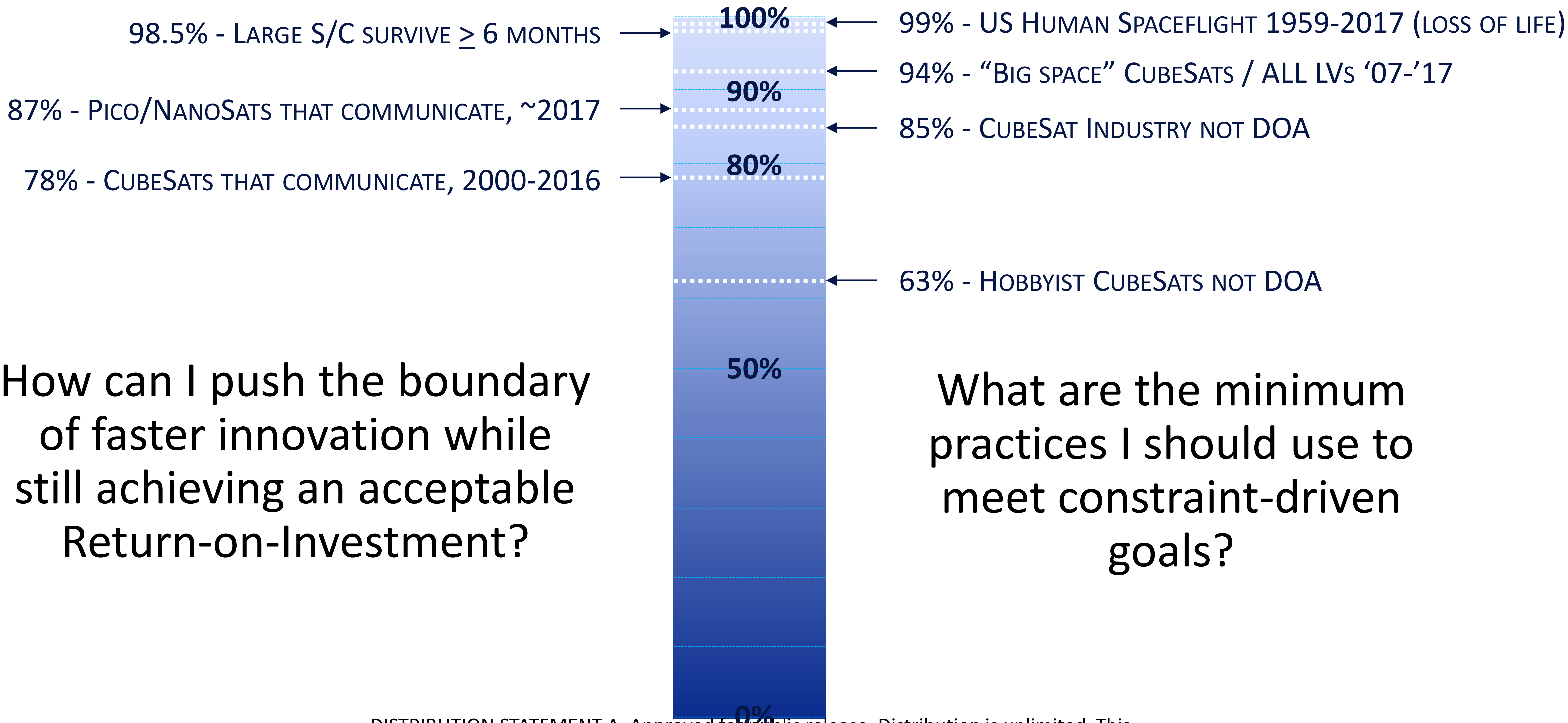
FASTER INNOVATION | LOW-COST DEVELOPMENT | EDUCATIONAL OPPORTUNITIES

In the wild west of today's MA:

22%

DoA

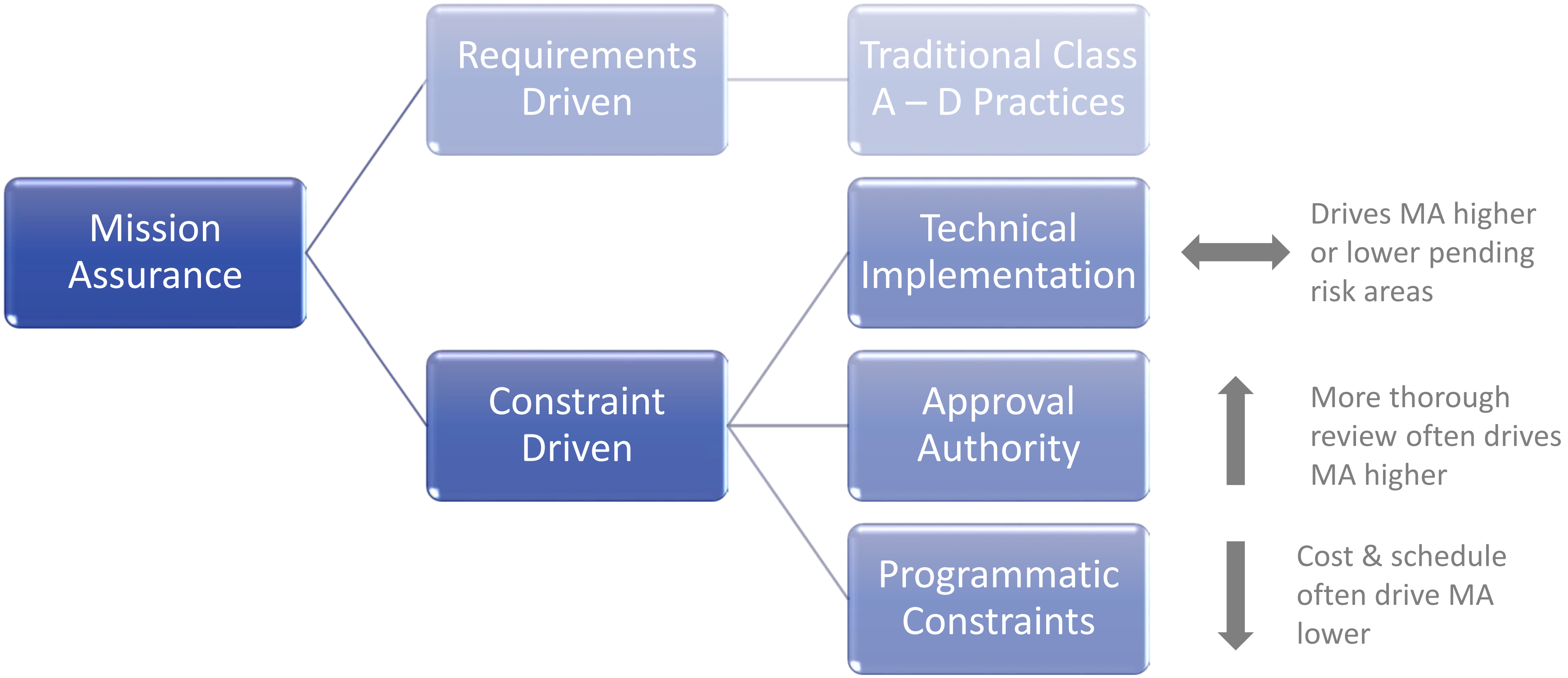
Percentage of Spacecraft Success



How can I push the boundary of faster innovation while still achieving an acceptable Return-on-Investment?

What are the minimum practices I should use to meet constraint-driven goals?

Elements of constraint driven MA



At inception, the stakeholders and designers should have an honest conversation about whether the mission is requirements or constraint driven

Technical implementation taxonomy

Demonstrated Level of Capability	Implication
Do No Harm	DOA is ok (education and/or fully constrained and not requirement driven)

All missions are designed for full mission success; the amount of mission assurance can provide a level of confidence in mission success

Technical implementation taxonomy

Demonstrated Level of Capability	Example Technical Activities	Example Approval Authority (AA)/Oversight	Programmatic
Do No Harm	Vibration testing, bake out, inhibit design review/test, range safety measures demonstrated, no RF transmission within 45 minutes of deployment/no attitude maneuvers within 15 minutes, 25 year deorbit.	AA: Program Reviews: informal peer, launch readiness.	Fully constrained, schedule + cost allow launch requirement verification only
Survival	(All of the above), possibly designing power/comm for tumble, long range communications testing with ground station has been completed(1), complete charge/discharge cycle testing completed(2), TVAC.	AA: Program Reviews: informal peer, may have stakeholder.	Mostly constrained, schedule + cost do not allow significant confirmation of capability beyond survival
Minimum Functionality	(All of the above), full command execution test(3), startup/POR DitL testing(4), Sun-point test(5), other mission specific tests demonstrating survival functionality, mission specific FTA & Self-EMC test, thermal analysis.	AA: Program +1 level Stakeholder input Reviews: informal-SCR, PDR, CDR, TRR, LRR	Mostly constrained, schedule + cost allow confirmation of capability to achieve minimum success
Nominal (**constraints**)	(All of the above), environmental characterization and flow down into requirements (i.e. radiation), full functional and limited performance testing, more detailed FTA & FMEA (flight, ground, GSE), SPF analysis/redundancy, requirement development to at least L2 and V&V.	AA: Program +2 levels Stakeholder input/vote Reviews: formal-SCR, PDR, CDR, TRR, LRR.	Less constrained and more requirement driven, schedule + cost allow confirmation of capability to achieve full success
Nominal (**requirements**)	(All of the above), full functional and performance testing, Worst Case Analyses & design. NPR 8705.4, TOR-2011(8591)-21	AA: Director Stakeholder vote/driven	Fully requirement driven, schedule + cost allow confirmation of capability to achieve full success

Case study: Competing objectives/constraints

SCENARIO: Multi-organization teaming

University Desired Approach: SURVIVAL

Professor believes educational intent met if some communication with satellite is achieved

→Work must primarily be done by students (mostly new team, 2nd sat of university)

→ Having the same students go through the entire process provides the best educational experience (~80% turnover in 2 years)

→ Need additional program funding

Company X Desired Approach: FULL SUCCESS

Company X wants to show their product works as expected on-orbit

→Only has internal funding to support spacecraft development activities related to their payload

→ No flight heritage of this product, paying customers not ready to assume risk

→Product is batch produced and as a result, several flight models are available

Launch Provider Y Expectation: DO NO HARM

Launch Provider Y is primarily concerned with safety of their launch vehicle on its first flight

→Schedule is 100% driven by the launch provider since they are financing this first flight.

→ Safety to the flight vehicle is non-negotiable

MISSION ASSURANCE RESULT:

SURVIVAL

Team/Stakeholder Discussion:

- University/Company X need teaming opportunities to achieve goals, both benefit from launch provider involvement
- Time is key driver- launch provider will not provide schedule flexibility & value to individual students decreases as development extends beyond their academic term
- Knowing that inexperienced personnel would be performing most of the spacecraft development work, Company X recognized it could mitigate some risk by flying with several university teams who have programs operating on similar timelines

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MISSION ASSURANCE RESULT:

SURVIVAL

Practical Implementation:

- All Do no harm/Survival testing
- DitL testing and full command execution test only if time permits
- Internal university reviews and approval, Company X supports all, but does not pass/fail, launch provider attends from CDR on, has final say in LRR

Case Study: Multi-Level Mission Assurance

Scenario: Company X plans to field a constellation of satellites

Phase 1: One satellite for proof-of-concept demo, use lessons learned in Phase 2

Phase 2: Field full constellation

Key Driver: Time – want to be first to market, investor ROI

Discussion

Investors & developers agree imperfect functionality in Phase 1 demo is acceptable as long as path forward exists by Phase 2

Testing the full set of satellites may be time intensive, especially if high-confidence in performance is needed before launch

Mission Assurance Result: MIXED

Phase 1: SURVIVAL

- Company X chooses lower MA approach to realize near-term results and maintain momentum

Phase 2: NOMINAL for a few/ MINIMUM SUCCESS for most

- One vehicle per batch undergoes rigorous testing for systematic failures, remainder undergo minimal assurance
- Phasing of production & launch staggered to allow improvements; (i.e. Full Mission Success assurance through on-orbit testing/demo instead of purely ground assurance practices

Conclusions

- New mission assurance profiles are needed that represent constraint driven mission sets
- Constraints ≥ science or technology objectives
- A clear scope and broad understanding of constraints drive implemented MA to have the greatest ROI
- Generally more constrained missions allow decisions in all areas to be made closer to the project implementers

Is this the right path? We want to engage with the community!

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