Rideshare Mission Assurance on Multi-Payload Missions

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ABSTRACT

Given the increasing number of missions that are including rideshares, an established method of assessing mission risks across programs with differing levels of risk tolerance is becoming essential.

The DoD Space Test Program has developed a method for Rideshare Mission Assurance (RMA) that seeks to allow missions with different risk tolerances to fly together on a single launch, while shielding each mission from external risks to on orbit performance. RMA is a process that allows all mission partners to accept self-induced or programmatic risks (termed payload mission assurance risks) without having to evaluate any circumstances beyond their direct control. RMA is not a "classic" mission assurance practice, as it does NOT take into account the on-orbit functionality of the payload being assessed, and only assures that it will "Do No Harm" (DNH) to any mission partners.

This paper details the basic criteria for assessing risks within the RMA process, as well as methods used to define and delegate these risks to the appropriate mission partners. Also included are the basic test levels recommended for proving compliance with the DNH premise of the RMA framework. The paper will also discuss the application of the RMA process to past and future missions.

INTRODUCTION

The increasing miniaturization of electronics is causing a growing number of organizations to develop and build highly capable small spacecraft (less than 400Kg). As the size and weight of spacecraft reduce, it is no longer a guarantee that only a single satellite will ride on each launch to space. Launch providers have begun looking at ways to add additional payloads as "rideshares" to utilize excess lift capability on both commercial and National Security Space (NSS) launches as a way of reducing costs.

Often, these rideshare-eligible small spacecraft are of an experimental nature and are more risk-tolerant than either the launch vehicle provider or the primary payload for the launch. In order to assure a Class-A program that adding a rideshare will not pose an operational threat to the mission at hand, the DoD Space Test Program (STP) has implemented a hybrid system of risk acceptance termed Rideshare Mission Assurance (RMA). The basis of the RMA process is to provide all mission partners with a degree of comfort that all payloads included on a mission will do no harm (DNH) to any operational aspect of the primary mission at large.

The RMA process does this by assessing each payload flying on a mission independently, against a tailored set of criteria. The primary concern is to ensure that the payloads are robust enough to survive the launch environments experienced on the ride to orbit. However, other areas are assessed as well, including any co-use of facilities during the launch campaign and the critical function inhibit scheme utilized by the payload.

All risks that come out of this assessment are broken into two categories: payload mission assurance and safety of flight. Payload mission assurance risks generally only pose a threat to the payload being assessed, and as such are accepted by each payload's Risk Acceptance Authority (RAA). Safety of flight risks are issues that could potentially harm other mission partners from the start of launch processing to spacecraft separation on orbit, and are elevated to the overall mission RAA.

Critically, the RMA process is not used to evaluate the on orbit operability and functionality of the payload being assessed. It is only used to assure other mission partners that the addition of a rideshare partner will not preclude the ability of the mission partner to successfully execute their mission. It is especially useful when the risk acceptance authority for the mission at large does not have a mission assurance or risk acceptance role for all of the individual spacecraft that are flying on the mission.

History & Future Use

The rideshare mission assurance process was developed by the Space Test Program, SMC/SD (now SMC/AD), and the Aerospace Corporation during the AFSPC-4 mission. This mission included a Space Experiment Review Board (SERB) payload (called ANGELS) built by the Air Force Research Laboratory and an SMC-provided primary payload (GSSAP). The AFSPC-4 mission was the first instance where STP was responsible for integrating a highly risk-tolerant auxiliary payload (APL) onto a launch with a highly risk-averse primary. Rather than mandating that ANGELS adopt a significantly more costly and time-consuming Mission Assurance regimen, STP developed the RMA process, which allowed ANGELS to accept its own programmatic risks, but ensured that the GSSAP mission wouldn't be jeopardized. Examples from the AFSPC-4 mission will be used to illustrate the implementation of the RMA process.

Looking forward, this process is being implemented on two STP-supported missions: the Space Test Program - 2 (STP-2) mission, and an upcoming Air Force launch that will host AFRL's EAGLE platform. STP-2 is an EELV certification flight opportunity for the Falcon Heavy, which is flying 13 ESPA and "ESPA grande" class payloads built by eight different contractors, plus 24U worth of cubesats. STP-2 is an excellent example of how the RMA process can ease the mission assurance certification of complex missions. Given the number of payloads and agencies involved in STP-2, and the fact that all of these mission partners have different risk tolerances, developing a certification strategy would ordinarily prove challenging. The RMA process, however, provides a framework to assemble a cohesive mission assurance strategy out of many disparate mission assurance practices and agencies. By dividing risk and risk acceptance into separate mission assurance and safety of flight categories, each individual mission can accept its own programmatic risks and perform its own mission assurance certification, with safety-of-flight risks evaluated and accepted at the mission level.

IMPLEMENTATION

Binning Risks

The RMA process works by breaking risks into categories: payload mission assurance and safety of flight.

Payload mission assurance risks are risks that affect the internal workings of an individual program. The process of ensuring that all of the instruments on board the spacecraft will be able to collect the data required to meet mission success criteria would fall into this category. Safety of flight risks, however, are risks that could affect another payload on the mission. A good example of this would be an improperly tested bus structure that could fail during launch, releasing foreign object debris (FOD) into the fairing.

Once properly categorized, pure mission assurance risks can be effectively ignored by the mission at large, because it is the responsibility of the payload provider to assess and mitigate those risks internally. This allows the overall mission management team to focus on how to address the safety of flight risks that could threaten multiple partners.

Not all risks fall into clear-cut categories. For example: a risk of a flight computer failing to survive launch (leaving a mission unable to turn on) would be considered a mission assurance risk, since at first glance, it poses no threat to the launch partners. However, if the mission requires deployment into a critical orbit (for example, GEO belt/ISS keep out zones/sun-synchronous orbits), the computer failure means that the spacecraft is no longer able to maneuver to avoid debris or clear its orbital spot at the end of life. This turns the mission assurance risk into a safety of flight issue. In cases like this, it is possible to change the mission parameters to move the risk from one category to another. Instead of deploying directly into the desired (critical) operational orbit, it is possible to deploy into a disposal orbit and then maneuver into the desired orbital slot. Now, a failure to be able to command the spacecraft has no chance of harming other parts of the mission, and the risk can be moved from the safety of flight category to the mission assurance category. This approach was used for the ANGELS spacecraft on the AFSPC-4 mission, which operates within the GEO belt. Instead of being released directly in its desired orbit, ANGELS was released after the second stage was moved into its disposal orbit, but before stage deactivation. This allowed the team to validate ANGELS' functionality and maneuverability before it could pose a threat to other spacecraft.

Launch Environments

Because of the nature of the do no harm analysis, most of the time and effort involved in the RMA process revolves around assessing both the robustness of the payload design, and the environmental testing regimen that is implemented. This is due to the proximity of the payloads to each other and to the launch vehicle (LV), as well as the extreme environments of launch. During this critical time, even minor issues can pose a serious risk to all mission partners, violating the DNH premise of the RMA process.

Because most Auxiliary Payloads (APL's) and rideshare missions are one-of-a-kind spacecraft that are built on a limited budget, there is rarely the opportunity to have separate qualification and flight units. This necessitates applying "proto-qual" test levels (defined in SMC-S-016) for structural considerations, and further analysis for risks that fall outside the structural realm.

While this section provides test level guidance, it is important to remember that risk tradeoffs must sometimes be made. The goal of the RMA process is to minimize the risk to the program at large. Under-testing the payload by deviating from the recommended test levels clearly introduces risk under the RMA process. However, over-testing, whether due to conservative environment definitions, over-excitation of resonant structures, or other factors, also introduces risk, both programmatic (schedule delays due to replacing items broken during the test) and technical (excessive fatigue on mechanical structures). Managing the spectrum of risk represents one of the primary challenges of the RMA process.

This challenge is further exacerbated by the reality of the rideshare process itself. Most rideshare mission partners must design, and sometimes build, their spacecraft before a launch is identified, and new entrant launch vehicles may not have flight-validated environments. Uncertainty about the actual launch environment typically results in conservative test specifications, which may increase risk of breakage and/or fatigue on the payloads during test.

Random Vibration

Random Vibration testing must prove that the populated spacecraft is capable of surviving the LV-induced random vibration environment with margin, and is assessed using a shaker table. The minimum test level is 3dB above the envelope of the LV-provided Maximum Predicted Environment (MPE) and the minimum workmanship level provided in SMC-S-016 (which is also published as the draft MIL-STD-1540E). Any notching included in the test must be based on valid technical rationale, use industry approved force limiting functions, and be approved before testing commences. Reducing test levels to prevent component responses from exceeding component qualification levels or the predicted capability of components are generally not valid technical rationales.

Acoustic

While most small spacecraft are primarily driven by the LV random vibration environment, many individual design elements remain acoustically sensitive. Deployable solar arrays, large antennas, and other lightweight structures will often remain acoustically driven in certain frequency ranges. If analysis shows that the spacecraft being assessed does have acoustic sensitivities, then actual testing is required to demonstrate DNH compliance. This testing can be performed either at the system level (recommended), or on just the sensitive components (allowable only if system level testing is impractical). Like the random vibration tests, acoustic tests should be performed to proto-qual levels in order to demonstrate margin, and all structures should be tested in their ascent configuration. Acoustic testing can only be waived if it has been collectively (launch integrator, customer, and payload) determined via analysis that no components of the spacecraft have acoustically sensitive components.

Shock

Historically, the driving shock event for any payload has been its own separation from the launch vehicle, and as such, an instrumented separation system test would provide the required insight into the robustness of the spacecraft. However, with the increasing use of low-shock separation systems (PSC Motorized Lightband, Ruag Clampband Opening Device) this assumption can no longer be made. Analysis of the shock levels imparted onto the payload by LV-induced shock events (ignition, lift off, stage cutoffs, stage reignites, fairing separation, rideshare partner deployment(s)) must be assessed against the envelope of instrumented spacecraft testing and the industry-standard 50 in/sec line (see MIL-STD-810G). Any exceedances must be assessed individually.

Contamination

All spacecraft must be assessed against the risk of contaminating sensitive components of other rideshare partners. The RMA process must ensure that nothing from the spacecraft being assessed can be re-deposited on critical components of rideshare partners. This includes both particulate matter and volatile compounds. This requirement is assessed by a combination of test (thermal vacuum) and analysis (materials lists, contamination control plans, line of sight to sensitive components). While thermal vacuum testing is generally considered an electrical test, the level and duration of the upper temperature soak can be used to demonstrate that any volatile compounds will have baked-out of the system and no longer pose a threat to the mission.

Particulate matter mitigation must be addressed prior to the first time payloads are in the same area, whether this happens after they are encapsulated in the fairing or in a co-used clean-room for launch processing. All spacecraft must be cleaned to a level that they will not cause a cleanliness violation for any other mission partner.

Other Areas of Consideration

Other areas, outside of launch environments, must be assessed as well if they pose a threat to safety of flight or ground processing. Some areas of particular concern include inhibits, pressure vessels, and EMI/EMC.

Electromagnetic Interference

Because most APL's are launched in a "powered down" state, EMI risks are generally assessed in relation to the spacecraft processing period. Radiated Emissions (RE) assessments of the spacecraft are performed to ensure that any functional testing in a co-used processing facility will not damage sensitive components of rideshare partners. In addition to the RE testing, Radiated Susceptibility (RS) assessments of the spacecraft must also be performed to provide inputs to all other rideshare partners' RMA analysis. These tests should be performed per MIL-STD-461E or equivalent. If incompatibilities are discovered in the RE/RS testing, simple mitigation steps can be implemented to reduce risk. Simple mitigation steps might include using antenna hats to eliminate free radiation, and organizing time-sequenced tests between spacecraft to allow for sensitive electronics to be safed.

Analysis must also be performed on the risks of accidental in-faring transmissions. For spacecraft launched in powered-down states the requirement for 3 inhibits on any transmitters mitigates this risk. For spacecraft that launch in a powered-on state, additional analysis and/or mitigations must be completed to ensure that any potentially damaging emissions are prevented from causing issues for rideshare partners.

Pressure Vessels

If rideshare spacecraft have pressurized systems such as propulsion, extensive testing must be performed to insure that no failures will occur during launch. Pressurized systems must be tested to proto-qual levels as described by SMC-S-016 (1.5x Maximum Expected Operating Pressure).

Electrical Inhibits

Industry standard requirements for inhibiting critical functions of the spacecraft are not tailorable under the RMA process (refer to AFI 91-710). At a minimum, there must be three inhibits to the activation of all critical functions. These include, but are not limited to: propulsion systems, any deployable structures such as solar arrays or antennas, as well as all transmitters. Verification of this requirement by analysis only is acceptable.

VERIFICATION

Any safety of flight risks discovered during the RMA process are documented and presented to the full mission team. If any are determined to pose an unacceptable level of risk to another mission partner, or to the mission at large, it is the responsibility of the spacecraft provider that is the source of the risk to either implement the necessary changes to mitigate the risk to an acceptable level, or to voluntarily remove themselves as a rideshare partner. The primary risk acceptance authority for the mission has the final say on whether or not any payload has met its do no harm requirements.

PROGRAM MANAGEMENT INSIGHT

For this process to work efficiently, sufficient insight into the spacecraft design, integration, and especially test process is required by the cognizant program management. This insight is not limited to the individual program's management authority, but must include the overall mission program management whenever safety of flight risks are involved. Integration and test methods must be detailed to the overall mission management team to insure that the methods and procedures implemented do not compromise otherwise sound designs, and that all components used in the buildup of the spacecraft conform to their respective design specifications. Furthermore, any post testing changes to the spacecraft (Component Remove & Replace, new/differing payloads, etc.) must be vetted by the program office prior to the implementation of the changes in order to ensure that there is no additional risk caused by the late stage changes.

The AFSPC-4 / ANGELS mission integration provides an example. AFSPC-4 experienced a launch delay, which provided ANGELS with a long storage period following environmental test. ANGELS used this opportunity to add components to their spacecraft to improve capability, thereby breaking configuration following environmental test. While this break in configuration did not violate ANGELS risk acceptance guidelines, it did pose an issue for the RMA process. This issue was ultimately addressed by a thorough analysis and risk acceptance process, but early communication, understanding, and acceptance of the RMA process might have prevented the issue from arising. Such early communication is already underway on the upcoming mission flying EAGLE, and discussions of the do no harm RMA criteria have already been held.

CONCLUSION

The rideshare mission assurance process, developed by the Space Test Program for use on the AFSPC-4 mission, provides a framework for performing mission assurance on multi-payload missions. It does this by breaking risks into categories, and assigning risk acceptance authority (RAA) levels based on how the risks impact other payloads on the mission. Mission assurance risks that only affect an individual payload can be accepted by that payload's RAA, while safety of flight risks must be elevated to the mission RAA. The criteria for categorizing all risks is "do no harm." Test levels for verification testing are generally at "proto-qualification" levels as specified in the relevant military or industry standard; however, rigid adherence to these levels could involve technical risk tradeoffs, or have significant cost or schedule implications. Engineering judgment must be used throughout the verification process.