AEROSPACE REPORT NO.
TOR-2016-02946-Rev A

Rideshare Mission Assurance and the Do No Harm Process

February 28, 2019

Andrew Read[1], Peter S. Chang[2], Barbara M. Braun[3], and David D. Voelkel[2]
[1]Advanced Development and Planning Division, Defense Systems Group
[2]Multi-Paylaod Mission Integration, Agile Space Acquisition and Implementation
[3]Agile Space Acquisition and Implementation, Space Innovation Directorate

Prepared for:

Space and Missile Systems Center
Air Force Space Command
483 N. Aviation Blvd.
El Segundo, CA 90245-2808

Contract No. FA8802-19-C-0001

Authorized by: Defense Systems Group

Distribution Statement A: Approved for public release; distribution unlimited.

AEROSPACE
Assuring Mission Success

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 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 set of tests 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.

Appendix A to this document contains a “Maximum Flight Opportunity” checklist. This checklist provides payload developers with a baseline set of requirements and verification methods that, if followed, simplify the “do no harm” certification process. It is also provides design criteria for missions looking to maximize their opportunity for rideshare and minimize launch costs.

Appendix B to this document contains the specific checklist that was developed by Aerospace in support of the STP-2 mission. This tailorable tool allows for easily organizing and assessing verification artifacts required by a rideshare mission.

Appendix C to this document contains a set of briefing charts that give an overview of the DNH process and illustrate the interactions between partners on a rideshare mission.

Contents

Figures

1. Scope

This paper is intended to provide guidance to the space industry on methods that can be used when designing and implementing multi-payload missions. Also included are design guidelines for spacecraft that will simplify being included on existing and future missions as a rideshare payload. It is important to note that the guidance contained in this document is presented as an outline. Derivative requirements can be either tailored or expanded to meet the realities of individual missions.

1.1 References

- *Evolved Expendable Launch Vehicle (EELV) Secondary Payload Adapter Rideshare Users Guide (ESPA RUG)*, May 2010
    - ESPA RUG change proposals 001 thru 009
- SMC-S-016, *Test Requirements for Launch, Upper-Stage and Space Vehicles*, September 2014
- ASTM E2900-12, *Standard Practice for Spacecraft Hardware Thermal Vacuum Bakeout*
- AFSPCMAN-91-710, *Range Safety User Requirements,* July 2004
- *Evolved Expendable Launch Vehicle Standard Interface Specification (EELV SIS) ,Revision B*
- Forgrave, John C et al. "*Acoustic and Random Vibration Test Tailoring for Low-Cost Missions*"
- MIL-STD-461G, *Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment,* December 2015
- GSFC-STD-7000, *General Environmental Verification Standard,* April 2005
- *Secondary Payload Planner's Guide For Use On The EELV Secondary Payload Adapter*, July 2006

2. Introduction

The increasing miniaturization of electronics is allowing a growing number of organizations to develop and build highly capable small spacecraft (less than 400Kg). As the size and weight of spacecraft decrease, launch purchasers have begun looking at ways to add payloads as "rideshares" to utilize excess lift capability on civil, commercial and National Security Space (NSS) launches.

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 risk-averse primary mission 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 objective of the RMA process is to provide all mission partners with a degree of certainty that all payloads included on a mission will do no harm (DNH) to each other, or to any operational aspect of the launch.

The RMA process does this by assessing each payload flying on a mission against a tailored set of criteria, known as "Do No Harm" criteria. The primary concern of the DNH process is to ensure that the payloads are robust enough to survive the environments experienced during launch. 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. Payload risks are separated 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 rest of the mission partners to successfully execute their mission. As such, it is not a traditional "mission success"-oriented mission assurance approach, but rather allows all mission partners to adopt their own mission assurance and risk acceptance approach for internal risks. It is especially useful when the RAA 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.

For the purposes of this document, "payload" refers to free-flying satellites deployed by a rideshare mission, and not to instruments or subsystems carried by these free-flying satellites. The term "satellite," "spacecraft," and "space vehicle" may also be used interchangeably with "payload" in this document.

2.1 History & Future Use

The rideshare mission assurance process was developed by the Space Test Program, SMC/SD (now SMC/AD), and the Aerospace Corporation over the course of several multi-payload missions, starting with STP-1 (launched March 2007). The process was later accepted as the formal mission assurance system for the AFSPC-4 mission and another Air Force launch that hosted AFRL's EAGLE platform. The AFSPC-4 mission included a Space Experiment Review Board (SERB) payload (called ANGELS) built by the Air Force Research Laboratory and an SMC-provided primary payload (two Geosynchronous Space Situational Awareness Program (GSSAP) satellites). 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 adopted and refined 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 the Space Test Program-2 (STP-2) mission. STP-2 is an EELV certification flight opportunity for the Falcon Heavy, and 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 and launch authorization 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 workable mission assurance strategy out of many disparate mission assurance practices implemented by many different 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.

3. Program Management Considerations

3.1 Applicability

This document is meant as an overview of the Do No Harm / Rideshare Mission Assurance process, and as a framework for implementing DNH / RMA on multi-payload missions. In most cases, details of the specific testing and design requirements are not addressed, but can be found in existing standards such as the Aerospace TR-RS-2014-00016 / SMC-S-016, *Test Requirements for Launch, Upper Stage, and Space Vehicles*, GSFC-STD-7000, *NASA General Environmental Verification Standard* (GEVS), and AFSPCMAN 91-710, *Range Safety User Requirements*, or in the mission-level Interface Control Document (ICD). Compliance with the guidelines given here does not guarantee compliance with contractual documents, which will vary by mission.

This document is designed to be applicable to all rideshare missions, regardless of the type of payloads being flown. This includes containerized spacecraft such as CubeSats in addition to more traditional rideshares or secondary payloads. In some cases, the RMA process may be applied to the container of containerized payloads, or tailored for situations where the container provides some degree of protection against DNH considerations.

3.2 Program Management Insight

For this process to work efficiently, sufficient insight into the spacecraft design, integration, and in particular, the test process, is required by the 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 understood by the overall mission management team to ensure that the methods and procedures implemented are sufficient to demonstrate DNH, and do not compromise otherwise sound designs. Furthermore, any post testing changes to the spacecraft must be vetted by the overall mission program management 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. Learning from the ANGELS mission, the mission team flying EAGLE began communicating and coordinating their "do no harm" RMA criteria much earlier.

3.3 Interagency & Mission Partner Agreements

Early understanding and agreement to an RMA baseline is important for all partners in a rideshare mission. Rideshare partners should discuss and come to a formal understanding of the following considerations related to RMA:

What is the RMA risk posture of the overall mission, and who is the mission risk acceptance authority? Highly risk-tolerant missions may fly with extremely risk-averse satellites or launch vehicles. Alternatively, all mission partners, including the launch vehicle, may be willing to tolerate increased risk, even for "do no harm" considerations. While the RMA approach allows missions to separate risks and delegate risk acceptance to the lowest level, all partners must understand the overall RMA risk posture and process to help avert misunderstandings as launch approaches. Whichever method is used, the process of defining the mission risk tolerance posture should begin as early as possible so that all mission partners know what will be required.

What are the DNH / RMA baseline tests, and will they be applicable to all partners? For example, rideshare mission managers may impose different requirements on containerized satellites, such as CubeSats, due to the protection afforded by their enclosures. Satellites that plan to be powered during ascent may have to conduct additional EMI testing. Primaries with high contamination sensitivity may require more stringent cleanliness requirements. All parties should have an understanding of the RMA baseline before commencing integration and test, or sooner if possible, since RMA considerations may impact satellite design.

What are the required verification artifacts? It is important to be clear as to when verification by analysis is acceptable, and when test is required. Guidelines for the delivery of test artifacts should also be provided. For example, will a test report be sufficient, or is raw data required? Must tests be witnessed? What level of independent review, if any, will be applied?

What is the process, and who are the approval authorities, for any RMA exceptions? RMA exceptions include *a priori* requests by missions to be exempted from DNH requirements. An example might be a CubeSat mission requesting relief from random vibration test levels, or a satellite requesting notching of the random vibration spectrum due to a sensitive component. All parties on a rideshare mission must understand the process for requesting such exceptions. More importantly, all rideshare partners must understand that such requests need to be made, and approved, before they are implemented.

What is the review process for any DNH violations? Violations differ from exceptions mainly in that they are identified "after the fact." For example, review of payload test data might indicate that test levels were insufficient to meet the imposed requirements. Alternatively, EMI testing might reveal a radiated emissions spike that could pose a danger to a partner mission. The process by which such violations are communicated, evaluated, and dispositioned should be understood by all parties.

What is the process for any post-environmental configuration changes? This will be addressed in further detail in Section 4.2.3, but satellites sometimes encounter the need to break configuration after the completion of environmental test. All parties on a rideshare mission should understand, up front, the process for changing configuration following the completion of RMA testing. As with RMA exceptions, all such configuration changes should be reviewed and approved by the overall mission risk acceptance authority prior to implementation.

Note that not all rideshare partners will know their launch mission before completing design, and sometimes even test. In these cases, the checklist in Appendix A provides guidance for ensuring the maximum availability of rideshare opportunities. Launch missions may ultimately impose more stringent requirements, but the checklist provides an “80% solution” that will help minimize launch costs and additional testing requirements for potential rideshares.

4. Implementation

4.1 Binning Risks

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

Payload mission assurance risks are risks that affect the internal workings of an individual payload. The process of ensuring that all of the instruments on board the spacecraft will be able to function and collect the data required to meet mission success criteria would fall into this category. Safety of flight risks, however, are risks that could affect the launch vehicle or 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 (e.g., geosynchronous orbit), 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 geosynchronous (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.

4.2 Defining Do No Harm Criteria

In order for the RMA process to be effective, all mission partners must work together to define not only the Do No Harm criteria for the mission, but also the artifacts required to demonstrate compliance. Appendix B to this TOR contains an example checklist that was developed by The Aerospace Corporation in support of the Space Test Program. This checklist provides an outline of example requirements that must be evaluated during a do no harm assessment. It is recommended that the requirements that flow out of the checklist be incorporated into the mission ICD and RVM (or another document managed by whichever organization is managing the DNH process for a given mission) for ease of organizing the verification artifacts provided by each rideshare partner. The checklist is fully tailorable and expandable to accommodate the realities of specific missions, and checklists developed by other launch providers may be substituted if they meet the same intent.

4.2.1 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.

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 design and test specifications, which may increase both the cost of the payload and the risk of fatigue or breakage on the payloads during test.

Finally, 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 generally necessitates testing to a protoqual-type level, usually 3dB above the mission's Maximum Predicted Environment (MPE).

4.2.1.1 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 MPE and the minimum workmanship level provided in SMC-S-016. No-test alternatives, such as showing positive margins when applying a 2.0 factor of safety (i.e. from NASA GSFC-STD-7000) can be used if agreed to by all mission partners. 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, and may constitute RMA exceptions or violations as described in Section 2.3.

4.2.1.2 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. Generally, structures should be considered acoustically sensitive if they have an area-to-mass ratio above 150in^2/lb . 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 MPE/Over All Sound Pressure Level +3db 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 provider and all payloads/program offices/other stakeholders) determined that no components of the spacecraft are acoustically sensitive, or that the spacecraft response to structurally-borne vibrations envelope the responses to the acoustic environment at all points across all frequencies.

4.2.1.3 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 (e.g., 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- or rideshare partner-induced shock events (ignition, lift off, stage cutoffs, stage reignites, fairing separation, rideshare partner deployment) must be assessed against the envelope of instrumented spacecraft testing and the industry-standard 50 in/sec line (see MIL-STD-810G). Any exceedances imposed by any rideshare partner must be assessed individually.

4.2.2 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. In some cases, safety to the space environment must also be considered. Some areas of particular concern include contamination, inhibits, pressure vessels, and EMI/EMC.

4.2.2.1 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 cycle or thermal vacuum) and analysis (materials lists, contamination control plans, line of sight to sensitive components). While thermal vacuum testing is generally considered an electrical stress 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 will not cause a cleanliness violation for any other mission partner.

4.2.2.2 Electromagnetic Interference

Because most APLs 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 three 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 (refer to AFSPCMAN 91-710).

4.2.2.3 Pressure Vessels

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

4.2.2.4 Electrical Inhibits

Industry standard requirements for inhibiting critical functions of the spacecraft are not tailorable under the RMA process. 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, and all transmitters. Verification of this requirement by analysis only is acceptable (refer to AFSPCMAN 91-710).

4.2.2.5 Debris Mitigation and End-of-Life Safing

The implication of rideshare to debris mitigation and end-of-life disposal must also be considered. This includes the consideration of risks to launch vehicle safing, such as the use of extra propellant for orbit changes, and any impacts on the launch vehicle’s ability to conduct end of mission disposal. While payload mission partners are responsible for their own orbital debris mitigation policy compliance, the launch mission owner may choose to assess the overall risk of harm to the space environment of all launching partners. This is not traditionally considered a part of RMA, but may be added by missions as deemed necessary.

4.2.3 Breaking System Configuration and Penalty Testing

The traditional SMC program desire is to perform all system-level dynamic testing with the goal of not breaking configuration for the remainder of the mission. This ideal is not always possible for a variety of reasons. During the system I&T progression toward launch, the removal and replacement (R&R) of components is a common occurrence. Reasons range from unexpected test anomalies that require the removal of a specific component for additional box level testing, to repair or replacement of malfunctioning units, and even to last-minute installation of flight batteries. These occasions can happen at all phases of the system test cycle, and the traditional (and ideal) remedial action is to apply ‘penalty testing’ so as to make the system ‘whole’ again and to prove its integrity/robustness after the configuration break.

In a majority of cases, the timing of these configuration breaks happen near the end of the I&T flow (TVAC or after), and to initiate a full system environmental retest could incur unrecoverable schedule and fiscal pressures on a program. However, the DNH risk from a broken configuration without any remediation is difficult to assess and is considered high. In order to reduce this risk without a system workmanship screen (acceptance level testing), the strength of the panels and associated fasteners must be scrutinized. Combination of augmentation schemes such as locking features, head staking, lubrication of dissimilar mating surfaces, and limited fastener reuse can all provide valid mitigation and potentially avoid penalty testing. The Moving Mechanical Assembly Standard AIAA-S-114-2005 provides guidance in panel/structural attachments where threaded fasteners are involved.

With the realities of R&R events during the integration campaign, it behooves the program (contractor and customer) to preplan and reach agreement on avoidance/mitigation measures in lieu of a complete revisit of the system environmental test sequence.

4.3 Managing DNH Verification

4.3.1 Interface Controls

Capturing DNH requirements in interface control documentation is one way to track compliance. In traditional one rocket/one payload missions, a mission ICD is maintained by the LV provider, while the payload provider, payload program office (PO), and LV PO support the development process and provide approval of the baseline ICD and any subsequent changes (see Figure 1 inset).In traditional one rocket/one payload missions, an ICD is maintained by an Integrating Contractor (IC) between the LV provider and the payload (PL) provider, while the payload program office (PO) supports the process (see Figure 1 inset). On multi-payload missions, the ICD must grow to not only encompass the additional LV – PL interfaces, but also to levy requirements on independent payloads as well. This causes an exponential growth of the number of interfaces that must be managed, along with all of their attached requirements.

Generally, these PL to PL interfaces aren’t physical, so they require special attention to detail. For example, past missions have had problems with highly magnetically sensitive components that could be damaged by the ferrous ground processing equipment used by other mission partners. The DNH process attempts to minimize the complexity of such requirements by imposing a standard set of DNH requirements on all payloads, but it is helpful to understand who will track, verify, and certify compliance with DNH.

There are many methods that can be used to manage the extra complexity of rideshare missions. Figures 1 and 2 below show two methods that have been used in the past, and how they compare to the traditional ICD process. The critical takeaway is that there must be a plan in place at the beginning of the mission regarding how all of these extra interfaces will be managed, what the required artifacts will be, and how those artifacts will be verified, particularly for DNH criteria. This also requires that the responsible parties must have a sufficient level of insight into the programs to be able to identify and de-conflict issues. Generating a mission specific boundary-map like those contained in figures 1 and 2 can help with this process.

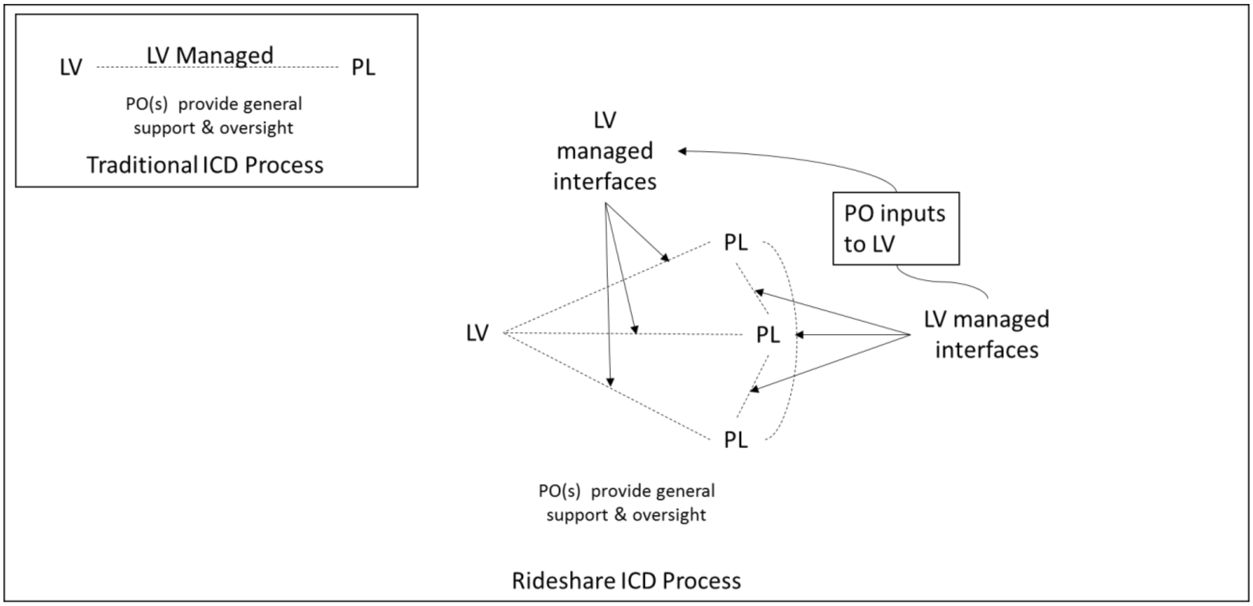


Figure 1: Rideshare ICD process and how it compares to traditional processes (inset)

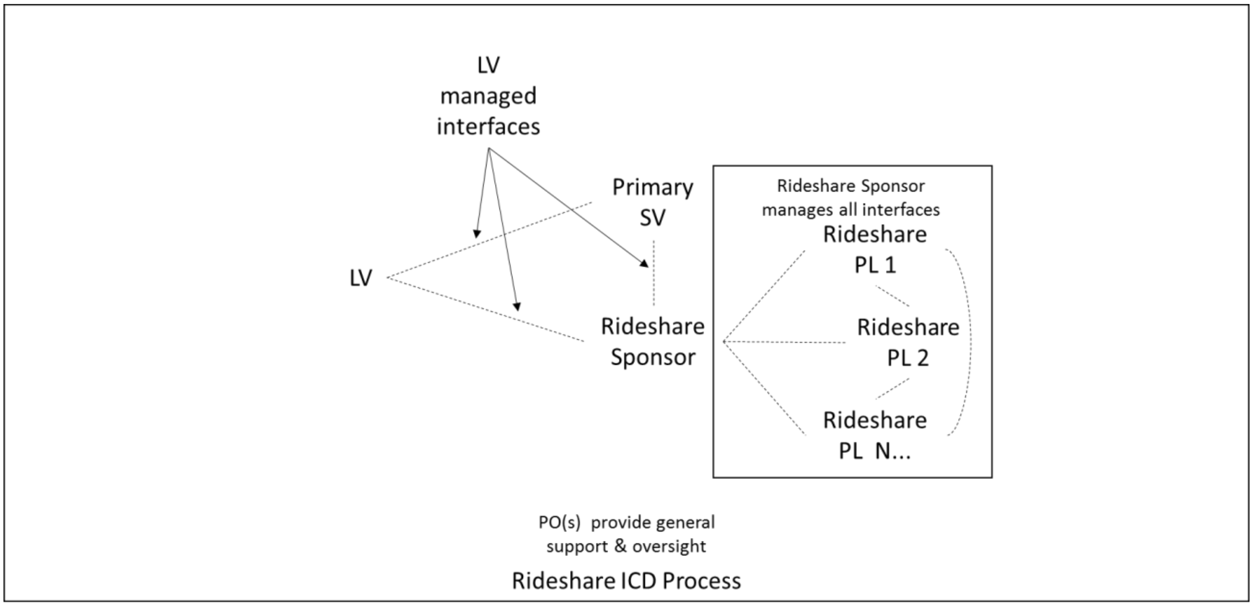


Figure 2: ICD Process with single rideshare point of contact

4.3.2 Verification and Risk Management

Once all mission requirements have been defined, the mission team must agree on acceptable methods for verifying that the requirements are met, and what artifacts must be provided so show compliance. Determining early in the mission which requirements can be verified through analysis as opposed to test is critical, as is determining whether or not a simple test report will suffice or if missions must provide more detailed test data for independent analysis.

Once verification artifacts have been provided, analysis can be performed to determine whether or not a rideshare payload has met the standards for the mission. 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 risk removal 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, in accordance with the established RMA approach as described in Section 2.3.

5. 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 a minimum of 3dB above the missions MPE; 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.

Appendix A. Maximum Flight Opportunity Guidelines

The checklist below contains requirements and verification methods that, if followed, simplify the “do no harm” certification process. It is also provides design criteria for missions looking to maximize their opportunity for rideshare. In particular, the mass, center of gravity, and fundamental frequency requirements listed below, while not typically considered true “do no harm criteria,” help facilitate a quick turnaround on the coupled loads analysis process, and are therefore included to enable more flexible manifesting of rideshares.

Meeting the requirements in this appendix does not guarantee that all “do no harm” criteria for every specific rideshare mission will be met; different missions may levy additional, or alternative, requirements depending on the particular sensitivities of the primary mission and the launch vehicle. Note also that violating these guidelines does not make a payload ineligible for inclusion as a rideshare. It will simply limit the number of missions that are compatible with the payload’s launch requirements, and may increase launch and integration costs.

A.1 Mechanical:

A.1.1 Spacecraft should fit fully within the envelope defined by the rideshare volume they wish to occupy. For example, an ESPA-class spacecraft should fit entirely within the ESPA envelope.

A.1.2 Spacecraft should use a standard separation interface as defined in the user’s guide for the payload adapter being used.

A.1.3 Spacecraft should maintain their center of gravity at 47.4±5.0% of the available payload volume and within 5.0% of the available payload volume width of the centerline with the origin at the center of the separation plane

A.1.4 Non-containerized spacecraft should use a standard low-shock separation systems to limit the shock imparted by separation, and to ensure acceptable safety in all potential deployment configurations (e.g., cantilevered, etc.).

A.1.4.1 ESPA Grande class

A.1.4.1.1 RUAG 24” CBOD

A.1.4.2 ESPA Class

A.1.4.2.1 Planetary Systems Corp. Mark II Motorized Lightband

A.1.4.2.2 Sierra Nevada Corp. 15LP

A.1.5 Containerized spacecraft should use the deployer for which they are designed

A.2 Static Loads:

A.2.1 Follow the levels identified by the ICD (or in the relevant appendix of the Rideshare User’s Guide). In the absence of existing guidance, use 8.5g applied at the CG.

A.2.2 Apply the max static load in any direction (use the root sum square of simultaneous loads) to every axis to ensure the spacecraft survives loads applied in any direction.

A.2.3 Programs may assess whether the random vibration environment envelopes the static load environment, and if so, use the random vibration test as their structural verification.

A.2.4 Compliance should be demonstrated by test, with 1.25 factors of safety applied.

A.3 Acoustic Environment:

A.3.1 Any spacecraft greater than 181.6kg (400lb) should undergo acoustic testing.

A.3.2 Any external spacecraft component with an area-to-mass ratio greater than 150in^2/lb should undergo acoustic testing, either as part of system testing (preferred) or as a subsystem.

A.3.3 Follow the levels identified by the ICD (or in the relevant appendix of the Rideshare User's Guide). In the absence of existing guidance, use the EELV SIS.

A.3.4 Programs may assess whether the random vibration environment envelopes the acoustic environment, and if so, use the random vibration test as their structural verification.

A.3.5 Compliance should be demonstrated by test, at the specified levels +3dB.

A.4 Random Vibration Environment:

A.4.1 Follow the levels identified by the ICD (or in the relevant appendix of the Rideshare User's Guide). In the absence of existing guidance, use:

Freq	PSD	Slope	Area
(Hz)	(g^2/Hz)	(dB/oct)	(g^2)
20	0.0065		
50	0.2000	11.26	2.082
100	0.2000	0.00	10.000
140	0.0500	-12.40	4.167
400	0.0500	0.00	13.000
1200	0.0500	0.00	40.000
2000	0.0050	-13.57	14.255
		GRMS:	**9.138**

A.4.2 First fundamental frequencies should be above 50 Hz, to minimally impact the coupled loads analysis and improve flight opportunities.

A.4.3 Force limiting may be used to limit the random vibration levels at resonant frequencies; all other notching methodologies should be avoided.

A.4.4 Compliance should be demonstrated by test, at the specified levels +3dB, with pre- and post-test sine sweeps to identify any frequency shifts

A.5 Shock Environment:

A.5.1 No spacecraft shock event prior to separation from the launch vehicle should generate more than 50 in/s of shock.

A.5.2 Spacecraft should be able to tolerate shock levels up to 50 in/sec .

A.6 Thermal Environment:

A.6.1 Spacecraft should be able to tolerate the ascent thermal environment without the use of heaters.

A.6.2 Spacecraft should undergo thermal bakeout per ASTM E2900

A.7 Contamination Environment:

A.7.1 Spacecraft should adhere to Class 100K cleanliness requirements, and be visibly clean of particulate matter before launch site processing.

A.7.2 Spacecraft should require no greater than Class 100K cleanliness levels.

A.8 EMI / EMC Environment:

A.8.1 Spacecraft should remain powered off from encapsulation through separation on orbit.

A.8.2 During launch processing, spacecraft should conduct no free radiation; antenna hats are acceptable for “plugs out” testing.

A.8.3 Spacecraft should ensure Underwriter Laboratory (or equivalent) certification on all EGSE.

A.8.4 Spacecraft should ensure radiated emissions from their EGSE and spacecraft during ground testing are below 20 V/M after attenuation.

A.8.5 Spacecraft should ensure magnetic cleanliness, with magnetic fields less than or equal to 1 Gauss at 1 meter from their spacecraft and all GSE.

A.9 Propulsion and Pressure Vessels:

A.9.1 Spacecraft should have no propulsion (preferred), or cold gas propulsion only (next most preferred).

A.9.2 Spacecraft with propulsion should use green propellant.

A.9.3 Pressure vessels should comply with Range Safety (AFSPCMAN-91-710) standards and be DoT certified.

A.10 Electrical Interfaces, Batteries, and Inhibits:

A.10.1 Batteries should be UL (or equivalent)-approved with no modifications and be compliant with Range Safety requirements (AFSPCMAN-91-710).

A.10.2 Spacecraft should require no electrical access after encapsulation, to include battery charging.

A.10.3 All inhibits to hazardous operations (such as deployments and radio turn-on) should be quadruple-redundant (triple-fault tolerant).

A.10.4 Spacecraft should inhibit deployments and transmitter turn-on for 45 minutes after deployment

Appendix B. Example Do No Harm Checklist

Detailed Description	Color	Short Description
This task has not yet been addressed (often with a requirement in the ICD) or there is a problem associated with this task.	🟥	**Not addressed, or it is a problem**
The program appear to be on track to accomplish the task or meet the requirement.	🟦	**On track**
The task is complete (e.g., requirement associated with this task has been verified by Aerospace and we have the artifact).	🟩	**Verified**
Task is not applicable (e.g., separation system test for non-separating payloads).	**Insert the words "Not Applicable" and leave unfilled (i.e., white)**	**The task is not applicable to the SV, satellite simulator, or CubeSat/PPOD. Describe why in column for "Notes and Description of Completion Artifact".**

Task	Completion Status (i.e., Color)	Notes and Description of Completion Artifact
Ensure SV meets mass property (i.e., mass, CG, inertia) requirements.		
Ensure SV static envelope meets requirements.		
Ensure SV separation system is compatible with LV separation signal		
Ensure SV separation system (or PPOD) mechanically fits the LV interface (e.g., hole pattern, flatness, connector type and location, clocking, fit check).		
Ensure fasteners between SV, separation system, and LV are strong enough for launch.		
Ensure electrical harness between the SV and the LV provide required separation signals and pass-throughs from the SV Electrical Ground Support Equipment (e.g., remote control and monitor SV and charge batteries as needed).		

Task	Completion Status (i.e., Color)	Notes and Description of Completion Artifact
Ensure LV interface harness and connectors provided by SV are properly built (length, bend radius, tie-off points & method, pin separation, shielding, splices, etc.)		
Ensure LV interface electrical harness pin-outs are defined and tested.		
Ensure all post-integration procedures for RBF/IBF are compliant with Do-No-Harm	Not DNH, though I could see making an exception for RBF / IBF hardware Clarified	
Ensure SV will not turn on transmitter until a time (e.g., 30 seconds) after separation from the LV.		
Ensure electromagnetic compatibility between SVs, between EGSE, and between SVs and EGSE for any pre-launch periods in which simultaneous operation are present or implement procedures so that no simultaneous operations occur.		
Ensure SV providers obtained approval from both payload processing facility management and the Range prior to the operation of any SV or ground support equipment transmitters while on the Range.		
Ensure appropriate SV inhibits (e.g., for propulsion, deployments, transmitters) to meet AFSPCMAN 91-710 are designed into the SV.		
Ensure SV radiated emissions do not exceed LV radiated susceptibility levels during launch.		
Ensure SV radiated susceptibility levels are compatible with LV and launch site radiated emissions levels.		
Ensure organizational responsibility is defined for propellant provision, fueling, and emergency contingencies.		
Ensure fueling procedures are compliant with Do-No-Harm	Wording change	

Task	Completion Status (i.e., Color)	Notes and Description of Completion Artifact
Ensure compliance with appropriate policy for the SV owning organization (e.g., imaging, propulsion, frequency approval, debris mitigation, etc.).		
Ensure SV magnetic requirements (e.g., payload processing facility, tools, other SVs) are defined if needed.		
Ensure the SV first modal frequency, when integrated with the separation system, meets the LV requirement.		
Ensure SV Finite Element Model (FEM) is correlated/verified to test per applicable standards (e.g., SMC-S-004 or NASA GSFC-STD-7000A, etc.)		
Ensure SV compares Coupled Loads Analysis results with SV design loads to ensure adequate SV strength.		
Ensure SV can withstand mechanical shock imposed at SV/LV interface without damage that could affect other SVs or the LV.		
Ensure the LV and SV evaluate LV plume impingement on the SV to avoid harm to the SV.		
Ensure launch base SV processing and LV integration roles and procedures are defined, feasible, and are compliant with Do-No-Harm.		
Ensure launch base SV processing space, facilities (e.g., storage, crane, safes, conductive flooring, office space, tables/chairs, phone, special gases), access (e.g., 3 weeks, 24/7), and services (e.g., security, cleanliness, temperature/humidity, internet, GPS, power, uninterruptable power supply) are defined and are compliant with Do-No-Harm		
Ensure SV can withstand maximum loads environments during transportation from processing facility to launch pad.		

Task	Completion Status (i.e., Color)	Notes and Description of Completion Artifact
Ensure SV requirements related to do no harm considerations for air temperature, humidity, cleanliness, flowrate, and gaseous purge through fairing encapsulation, transportation, and mating operations are met.		
Ensure SV separation, direction, timing are reasonable in the deployment sequence to reduce short-term and long-term (one year) probability of collision with other SVs.		
Ensure LV provider provides orbital state vectors to SV team post-deployment.	Not sure the reporting requirement is a DNH requirement. Clarified, I would argue that it is in the event of an off-nominal deployment location	
Ensure maximum limits on LV body rates (i.e., rate of roll, pitch, and yaw) related to do no harm considerations at SV separation are defined by the SV if desired.		
Ensure the LV performs Collision/Contamination Avoidance Maneuvers (C/CAMs) as necessary after each SV deployment to preclude re-contact between the LV and any deployed SVs.		
Ensure SV Remove Before Flight and Install Before Flight items are listed with Remove or Install time requirements.		
Ensure SV requirements for battery charging and termination of battery charging are defined.		
Ensure coordinate systems (LV, SV, separation system) are well defined and consistent with each other.		
Ensure the SV is compatible with the fairing dynamic envelope.		
Ensure electrical resistance between SV and LV meets requirement.		

Task	Completion Status (i.e., Color)	Notes and Description of Completion Artifact
Ensure separation system deployment options meet do no harm requirements (e.g., number of springs, spring force, spring locations, disconnect force).		
Ensure SV survives quasi-static loads from LV during launch.		
Ensure analysis is performed to determine whether random vibration test, acoustic test, or both should be performed on the SV.		
Ensure the SV passes random vibration and/or acoustic testing (as determined appropriate) without a failure that would cause harm to another SV or the LV.		
Ensure SV can survive fairing pressure decay rate during launch vehicle ascent without a failure that would cause harm to another SV or the LV.		
Ensure the SV separation system is within acceptable temperature range at time of SV separation.		
Ensure SV exposed surfaces comply with do no harm visible cleanliness requirements (e.g., Visibly Clean Level 2 or other specified requirements).		
Ensure SV delays any post-separation mechanical deployments and attitude adjustments until clear of LV.		
Ensure SV inhibits are compliant with Do-No-Harm	Inhibits? Clarified	
Ensure SV meets deployment separation velocity and tip-off requirements.		
Ensure SV locking features are used on fasteners that might contact other SVs if they come loose		
Ensure SV particulate contamination control sufficient to meet do no harm requirements (e.g., inspection and cleaning before integration to the IPS, review of SV materials to minimize shedding and flaking).		

Task	Completion Status (i.e., Color)	Notes and Description of Completion Artifact
Ensure SV molecular contamination control sufficient to meet do no harm requirements (e.g., requirements on total mass loss and volatile condensable matter, vacuum baking).		
Ensure SVs do not harm each other with radiated emissions during launch site processing		
Ensure separation systems are stowed properly for on-orbit separation		
Ensure SV primary structure and separation system are strong enough to survive launch		
Ensure Orbital Debris mitigation processes applicable to the SV owning organization are met		

Appendix C. Do No Harm Briefing

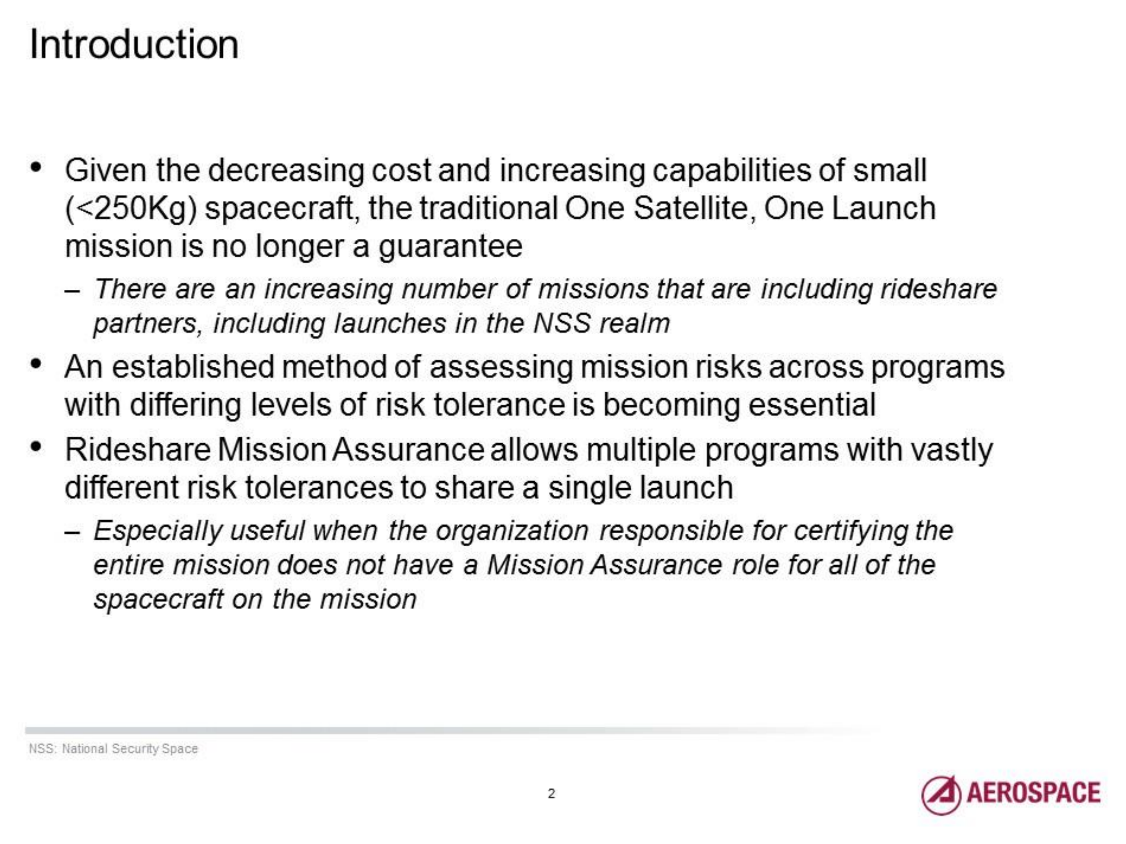
The following pages contain briefing charts that explain the Do No Harm process, and illustrate the interactions between partners on a rideshare mission. They were originally presented at the 2015 Small Satellite Conference in Logan, UT.

AEROSPACE
Assuring Space Mission Success

Rideshare Mission Assurance on Multi-Payload Missions

Andrew Read
Member, Technical Staff
The Aerospace Corporation

Space Innovation Directorate
August 12, 2015



Introduction

- Given the decreasing cost and increasing capabilities of small (<250Kg) spacecraft, the traditional One Satellite, One Launch mission is no longer a guarantee
  - *There are an increasing number of missions that are including rideshare partners, including launches in the NSS realm*
- An established method of assessing mission risks across programs with differing levels of risk tolerance is becoming essential
- Rideshare Mission Assurance allows multiple programs with vastly different risk tolerances to share a single launch
  - *Especially useful when the organization responsible for certifying the entire mission does not have a Mission Assurance role for all of the spacecraft on the mission*

NSS: National Security Space

AEROSPACE

Rideshare Mission Assurance/Do-No-Harm

Where did it come from?

- The AFSPC-4 mission included an SMC primary payload (GSSAP) and an AFRL provided APL (ANGELS)
- This created a clash of cultures between a traditionally risk averse primary payload and a much more risk tolerant APL
  - *This forced the development of a hybrid mission assurance system that would allow all mission partners to accept mission risks independently*
- Rideshare Mission Assurance/Do-No-Harm (RMA/DNH) is a process by which risk acceptance can be downwardly delegated to the lowest possible authority for a given rideshare partner
  - *Allows mission partners to accept all self induced/programmatic risks without having to evaluate any circumstances beyond their direct control*

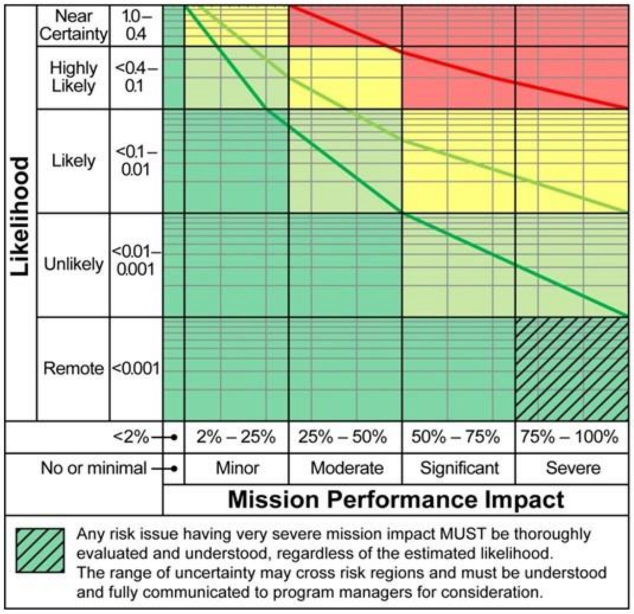
SMC: Space and Missile Systems Center
AFRL: Air Force Research Labs
GSSAP: Geosynchronous Space Situational Awareness Program
APL: Auxiliary Payload

ANGELS: Automated Navigation and Guidance Experiment for Local Space
RMA: Rideshare Mission Assurance
DNH: Do No Harm

Rideshare Mission Assurance/Do-No-Harm

What Is It?

- A process that focuses on insuring that no payload on a rideshare mission will negatively affect the on-orbit functionality of any other payload.
- The Aerospace risk identification and capture process is unchanged
  - *Guides which of the identified risks require further effort/mitigation*



▨ Any risk issue having very severe mission impact MUST be thoroughly evaluated and understood, regardless of the estimated likelihood. The range of uncertainty may cross risk regions and must be understood and fully communicated to program managers for consideration.

RMA/DNH does NOT take into account the on-orbit functionality of the payload being assessed

Rideshare Mission Assurance/Do-No-Harm

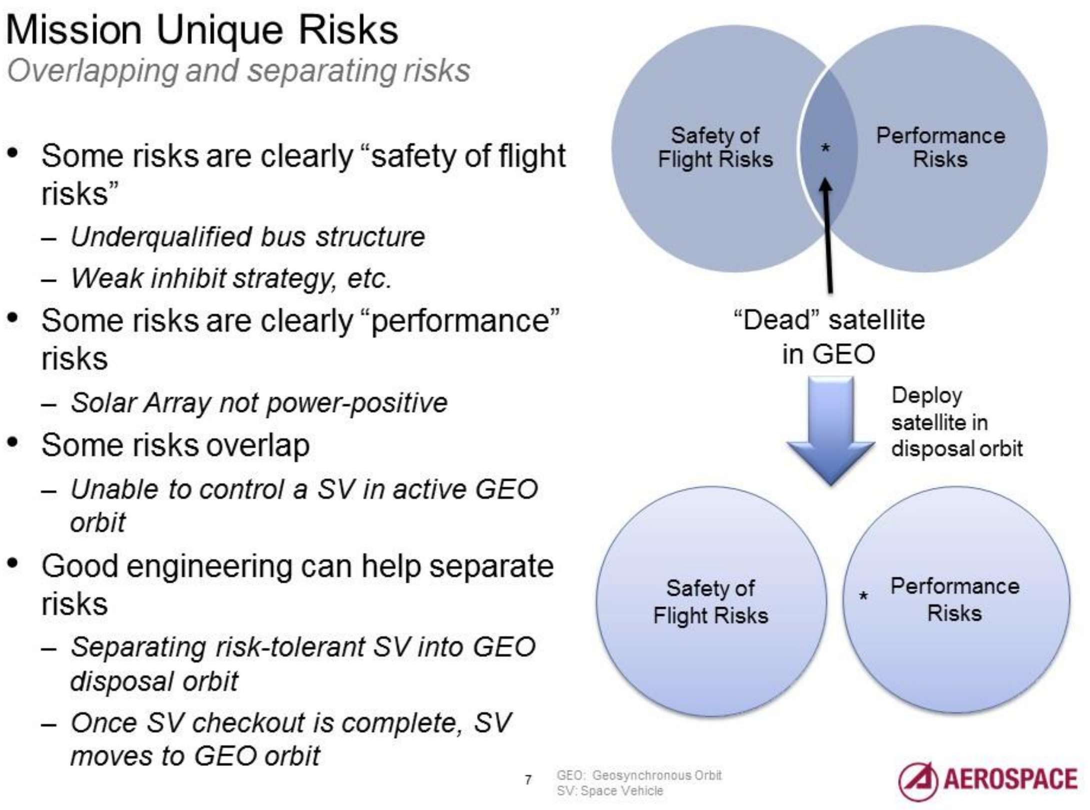
Cradle to Grave process

Design	Build	Test	Launch Integration	Launch	Operations/ End of Life
• Design Loads • Electrical inhibits	• Implementation of design criteria and military standards	• Qualification regimen • Appropriate margin	• De-confliction of joint operations	• Deployment sequence	• Safing • Disposal • Deorbit

Mission Unique Risks

- RMA/DNH allows Mission Managers to break all payload related mission risks into two categories
  - *Payload Mission Success*
  - *Safety of Flight*
- Mission success risks are accepted by each individual payload's Risk Acceptance Authority
  - *These risks only affect the functionality of an individual payload*
  - *Risks that are generally considered "mission assurance" or "system safety"*
- Safety of Flight risks are accepted by the mission team as a whole
  - *Only risks that pose a threat from the start of launch processing until SV separation*
  - *Risks that are generally considered "space safety"*

RMA: Rideshare Mission Assurance
DNH: Do No Harm

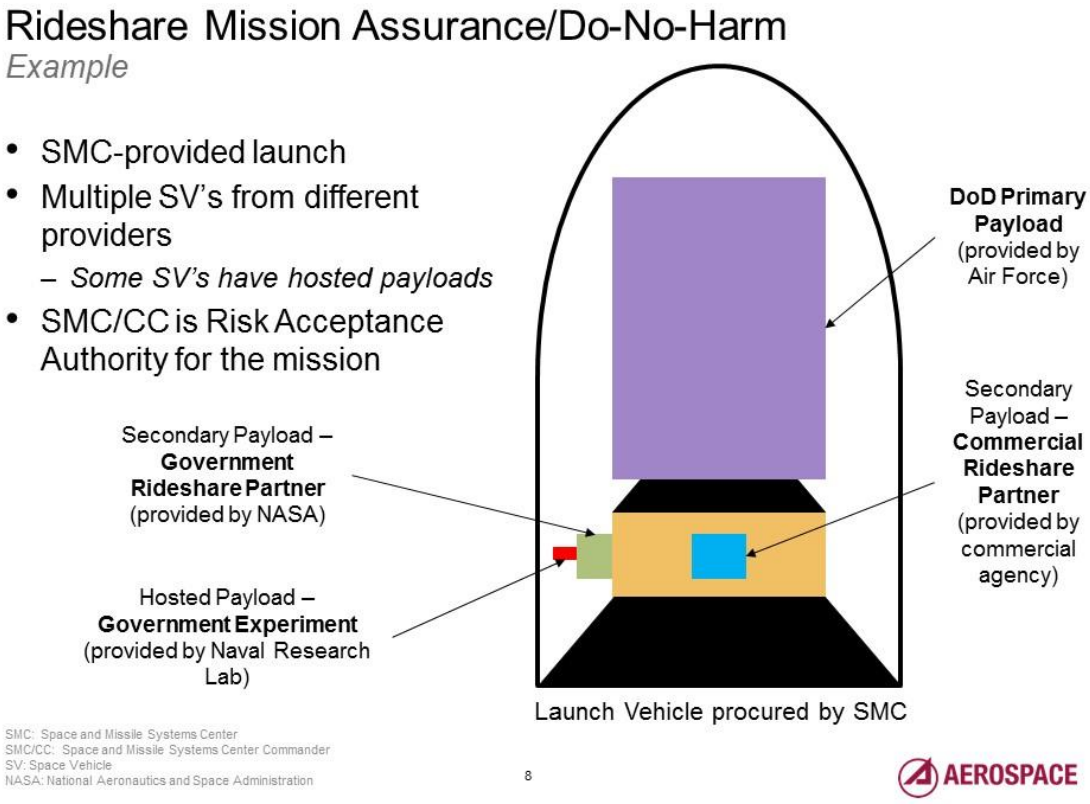


Mission Unique Risks

Overlapping and separating risks

- Some risks are clearly “safety of flight risks”
  - *Underqualified bus structure*
  - *Weak inhibit strategy, etc.*
- Some risks are clearly “performance” risks
  - *Solar Array not power-positive*
- Some risks overlap
  - *Unable to control a SV in active GEO orbit*
- Good engineering can help separate risks
  - *Separating risk-tolerant SV into GEO disposal orbit*
  - *Once SV checkout is complete, SV moves to GEO orbit*

GEO: Geosynchronous Orbit
SV: Space Vehicle



Rideshare Mission Assurance/Do-No-Harm

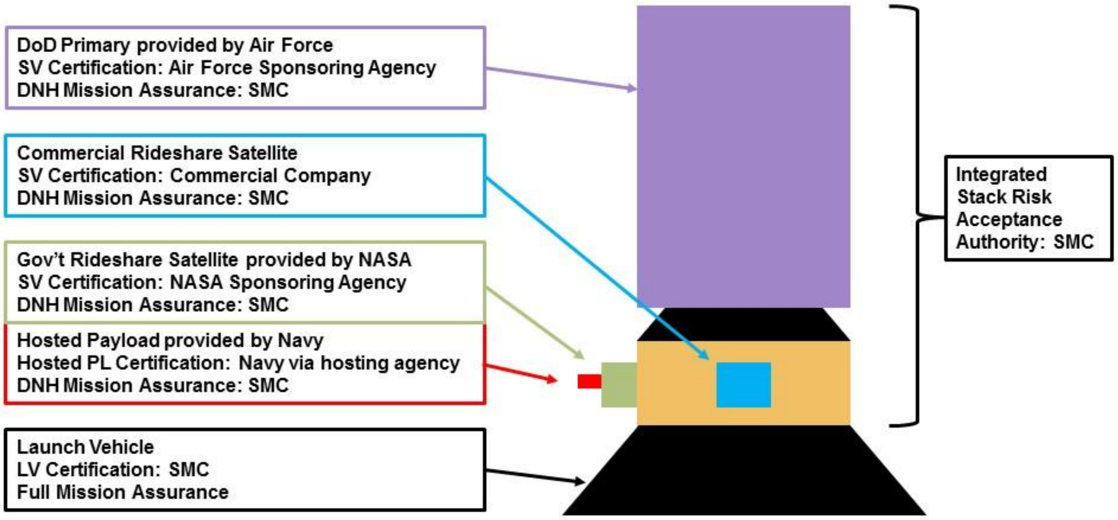
Example

- SMC-provided launch
- Multiple SV’s from different providers
  - *Some SV’s have hosted payloads*
- SMC/CC is Risk Acceptance Authority for the mission

SMC: Space and Missile Systems Center
SMC/CC: Space and Missile Systems Center Commander
SV: Space Vehicle
NASA: National Aeronautics and Space Administration

Rideshare Mission Assurance/Do-No-Harm

Certification



DoD Primary provided by Air Force
SV Certification: Air Force Sponsoring Agency
DNH Mission Assurance: SMC

Commercial Rideshare Satellite
SV Certification: Commercial Company
DNH Mission Assurance: SMC

Gov't Rideshare Satellite provided by NASA
SV Certification: NASA Sponsoring Agency
DNH Mission Assurance: SMC

Hosted Payload provided by Navy
Hosted PL Certification: Navy via hosting agency
DNH Mission Assurance: SMC

Launch Vehicle
LV Certification: SMC
Full Mission Assurance

Integrated Stack Risk Acceptance Authority: SMC

DoD: Department of Defense
SV: Space Vehicle
SMC: Space and Missile Systems Center
NASA: National Aeronautics and Space Administration
PL: Payload

Rideshare Mission Assurance/Do-No-Harm

Summary

- Each agency provides its own Mission Assurance and certification letter for their own spacecraft
  - *Verification artifacts are provided with the certification letter to provide inputs to the DNH analysis*
- SMC with Aerospace support provides the Do No Harm mission assurance assessment for the payload stack
- SMC/CC will provide certification for the mission as a whole

DNH: Do No Harm
SMC: Space and Missile Systems Center
SMC/CC: Space and Missile Systems Center Commander

Rideshare Mission Assurance/Do-No-Harm

Expanded System Example: STP-2

- The STP-2 Mission
  - *2 Co-prime Missions*
    - DSX – Provided by AFRL
    - Formosat-7/COSMIC-2 – Provided by NSPO (Taiwan) with US Air Force instruments
  - *6 Auxiliary Payloads*
    - NASA
    - Surrey Satellite Technologies US
    - Georgia Tech
    - Michigan Tech
    - US Air Force Academy
    - Naval Postgraduate School
  - *24U of Cubesats*

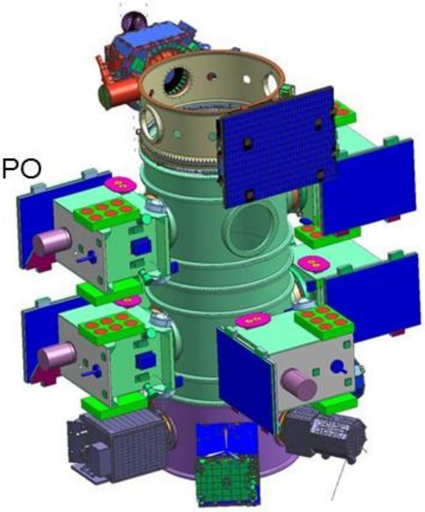


Photo courtesy of SpaceX

AFRL: Airforce Research Labs
NSPO: National Space Organization (Taiwanese Space Agency)
NASA: National Aeronautics and Space Administration
STP: Space Test Program

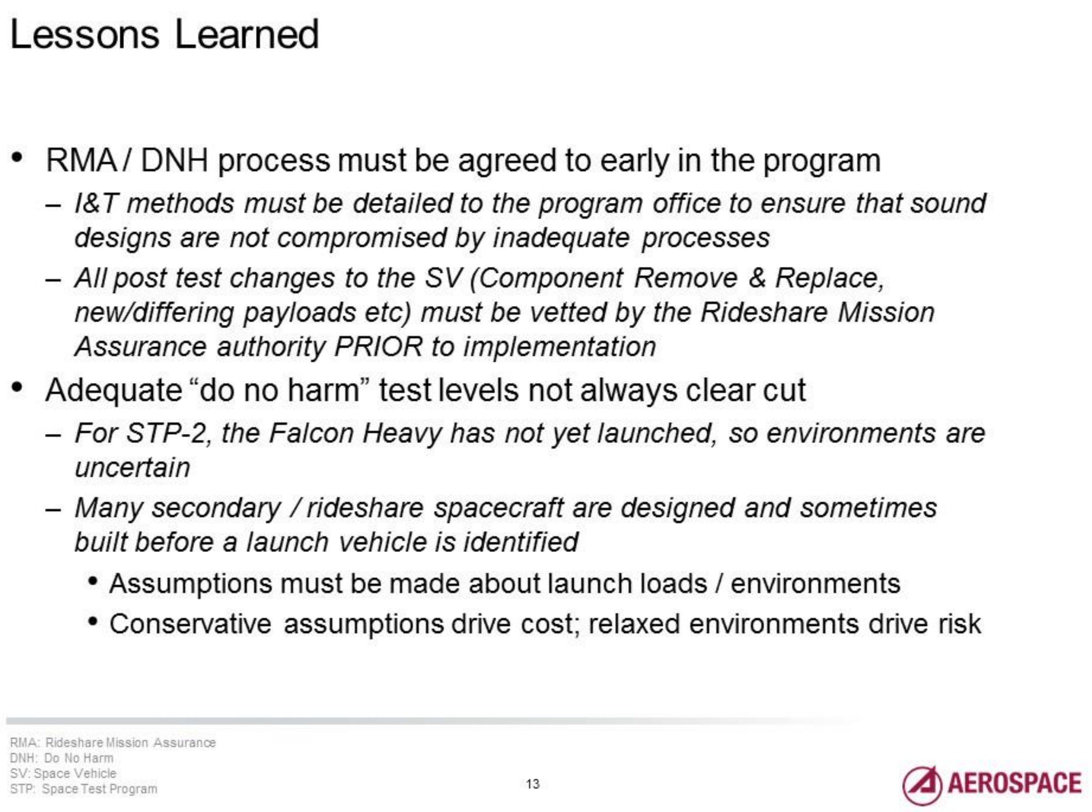
DSX: Demonstration Science Experiment
COSMIC: Constellation Observing System for Meteorology, Ionosphere, and Climate

---

DNH Relevant Testing

- Random Vibration
  - *Generally tested to proto-qual (MPE +3dB)*
- Acoustic
  - *Also tested to proto-qual*
  - *Can be waived if SV does not have acoustically driven components*
- Shock
  - *Measured against industry standard 50in/sec line*
- Outgassing & Contamination
  - *Primary concern is to protect optics*
- EMI/EMC
  - *Focused on ground operations in co-processing facilities*
- Inhibits
  - *Three required for all critical functions*

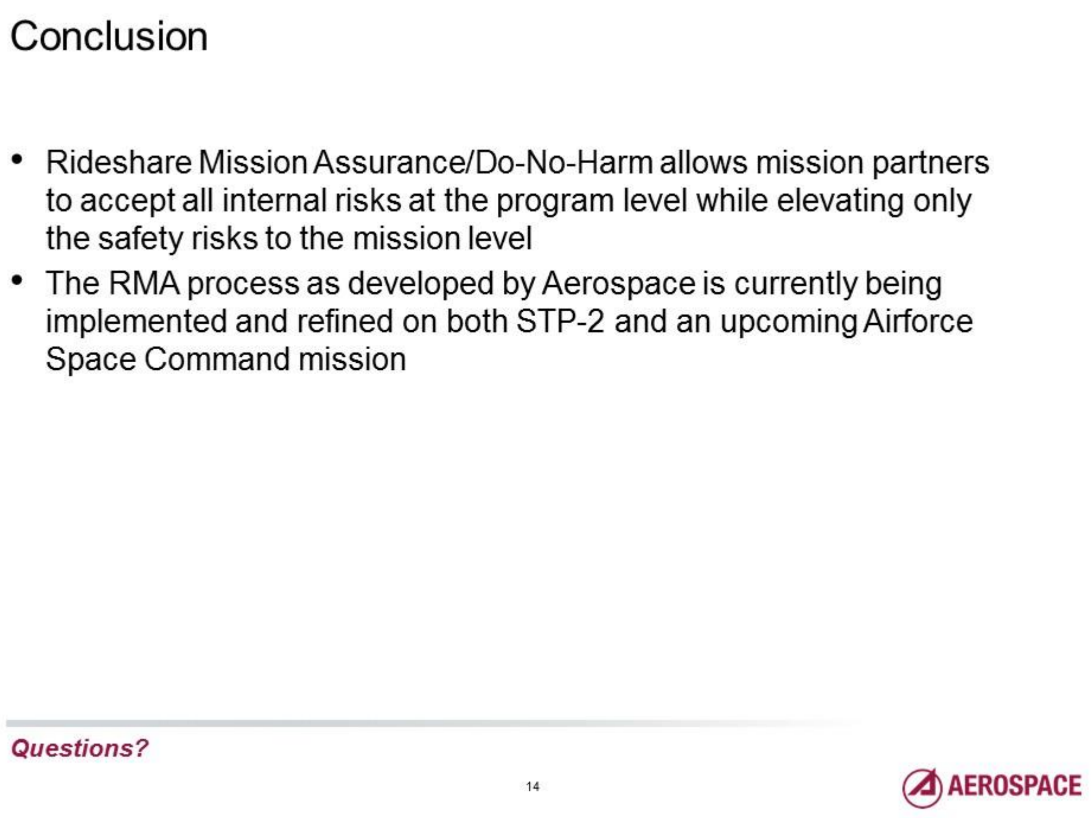
EMI: Electromagnetic Interference
EMC: Electromagnetic Compatibility
MPE: Mean Predicted Environment



Lessons Learned

- RMA / DNH process must be agreed to early in the program
  - *I&T methods must be detailed to the program office to ensure that sound designs are not compromised by inadequate processes*
  - *All post test changes to the SV (Component Remove & Replace, new/differing payloads etc) must be vetted by the Rideshare Mission Assurance authority PRIOR to implementation*
- Adequate "do no harm" test levels not always clear cut
  - *For STP-2, the Falcon Heavy has not yet launched, so environments are uncertain*
  - *Many secondary / rideshare spacecraft are designed and sometimes built before a launch vehicle is identified*
    - Assumptions must be made about launch loads / environments
    - Conservative assumptions drive cost; relaxed environments drive risk

RMA: Rideshare Mission Assurance
DNH: Do No Harm
SV: Space Vehicle
STP: Space Test Program



Conclusion

- Rideshare Mission Assurance/Do-No-Harm allows mission partners to accept all internal risks at the program level while elevating only the safety risks to the mission level
- The RMA process as developed by Aerospace is currently being implemented and refined on both STP-2 and an upcoming Airforce Space Command mission

Questions?

Backups

Space Flight Worthiness Criteria

- On past missions, the standard SMC SFWC was tailored by a joint SMC/SV provider team.
- Based on the latest mission, each section had varying degrees of relevance:
  - *Operational Safety: 6 of 21 Not Applicable*
  - *Operational suitability: 32 of 123 N/A*
  - *Operational effectiveness: 12 of 24 N/A*
  - *Mission certification: 1 of 21 N/A*
- A “generic” tailoring is currently in process that will be applicable to all future rideshare missions

Random Vibration

- Must prove that the populated SV is capable of surviving the LV induced random vibration environment with margin
- Assessed by minimum base-shake test levels
  - *Generally MPE+3dB*
- Notching based on industry approved force limiting functions must be approved before testing commences
  - *Notching must be based on valid technical rationale*
    - Wanting to keep component responses during system-level testing from exceeding (a) predicted capability, (b) previously specified component environments, or (c) levels that simply make you nervous is NOT valid technical rationale!

Acoustic

- Can be waived if it has been collectively (launch integrator, customer, and payload) determined that no components of the SV have acoustically sensitive components
- However, many design elements are sensitive even on small sats
  - *Deployable solar arrays*
  - *Large antennas*
  - *Other lightweight structures*
- Acoustic testing can be performed at the system level (recommended), or on just the sensitive components (Only if system level is impractical)
  - *Levels should be MPE+3dB*
  - *Test should be run with the SV and/or components in their ascent configuration*

Shock

- Ensure that the shock level imparted by various launch events will not cause physical damage the SV being assessed that could cause FOD
- Shock events can be divided into SV induced and LV induced
  - *SV induced shock*
    - SV separation/deployment event from the LV
    - Assessed by performing an instrumented separation test
  - *LV induced shock*
    - All ascent events: ignition, lift off, stage cutoffs, stage reignites, fairing separation, rideshare partner deployment(s)
      - *Generally, the shock levels of these events onto the payloads are attenuated greatly via various levels of mechanical interfaces.*
    - Assessed by analysis, using flight heritage data when available
- Results of the LV assessments are compared to the envelope of the instrumented SV test and the industry-standard 50 in/sec line
  - *Any exceedances assessed individually*

Outgassing & Contamination

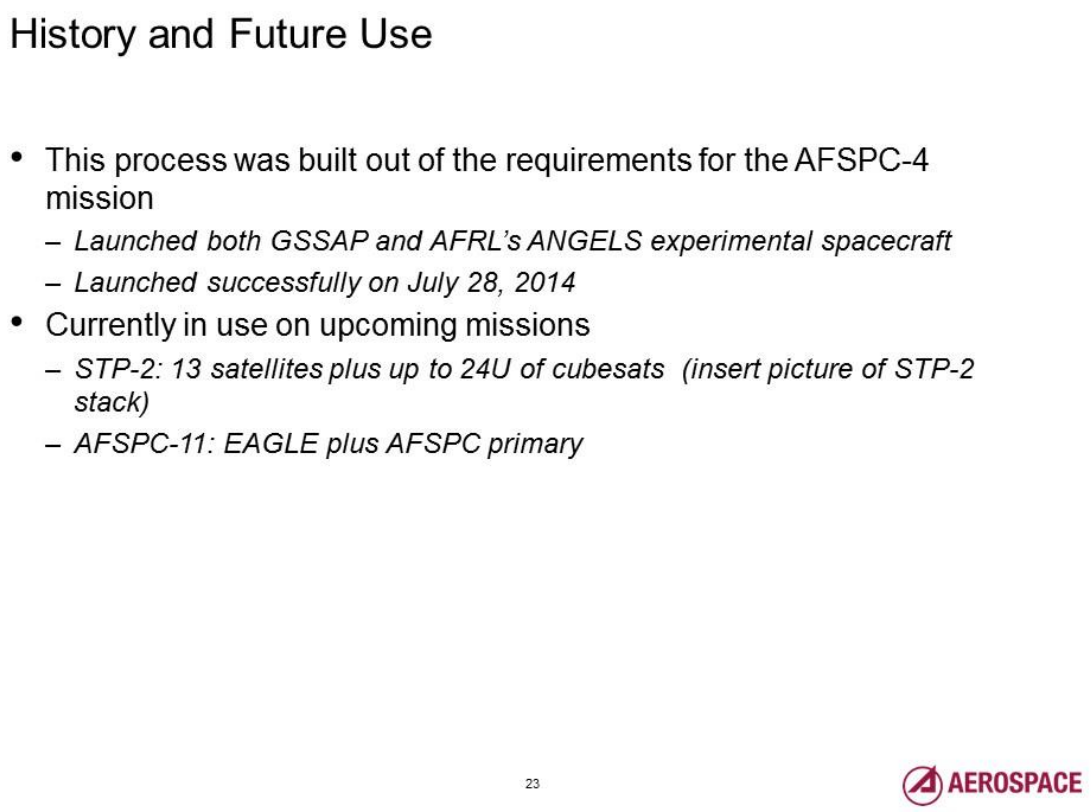
- Must ensure that nothing from the spacecraft being assessed can re-deposit on critical components of rideshare partners
  - *Includes both particulate matter and volatile compounds*
- Assessed using
  - *SV Materials lists*
  - *APL contamination control plan and cleanliness requirements*
  - *Thermal Vac test protocols (level and duration of upper temperature soak)*
  - *Line of sight to sensitive components*

EMI/EMC

- Because most APL's are launched in a "powered down" state, EMI risks are generally assessed in relation to the SV Processing period
- Radiated Emissions assessments of the SV is performed to ensure that any functional testing in a co-used processing facility will not damage sensitive components of rideshare partners
  - *Radiated Susceptibility assessments of the SV must also be performed to provide inputs to all other rideshare partners RMA/DNH analysis*
- Analysis is also performed on the risks of accidental in-faring transmissions
  - *Mitigated by the requirement for 3 inhibits on any transmitters*

Inhibit scheme

- Industry standard requirements for inhibiting critical functions of the SV are not tailorable under DNH mission assurance (refer to AFI 91-710).
- Three inhibits required for critical functions:
  - *Propulsion system*
  - *All deployables*
    - Solar Arrays
    - Antennas
  - *All transmitters*



History and Future Use

- This process was built out of the requirements for the AFSPC-4 mission
  - *Launched both GSSAP and AFRL's ANGELS experimental spacecraft*
  - *Launched successfully on July 28, 2014*
- Currently in use on upcoming missions
  - *STP-2: 13 satellites plus up to 24U of cubesats (insert picture of STP-2 stack)*
  - *AFSPC-11: EAGLE plus AFSPC primary*

AEROSPACE

External Distribution

REPORT TITLE		
Rideshare Mission Assurance and the Do No Harm Process		
REPORT NO. TOR-2016-02946-Rev A	PUBLICATION DATE April 26, 2019	SECURITY CLASSIFICATION UNCLASSIFIED

Col. John Anttonen SMC/AD John.Anttonen@us.af.mil	Mr. Theodore Marrujo SMC/ADS Theodore.Marrujo@us.af.mil
Col. D. Jason Cothern SMC/ADS Donald.Cothern@us.af.mil	Mr. Lonny Webb SMC/ADS Lonny.Webb.1@us.af.mil
Maj. Dell Olmstead SMC/ADS Dell.Olmstead@us.af.mil	Dr. Claire Leon SMC/LE Claire.Leon@us.af.mil
Mr. Michael Marlow SMC/ADS Michael.Marlow@us.af.mil	Mr. Randy Riddle SMC/LEX Randall.Riddle.3@us.af.mil
Mr. Kenneth Reese SMC/ADS Kenneth.Reese@us.af.mil	Lt. Col. Robert Atkins SMC/LEG Robert.Atkins.3@us.af.mil

APPROVED BY____ DATE______________
(AF OFFICE)

AEROSPACE REPORT NO.
TOR-2016-02946-Rev A

Rideshare Mission Assurance and the Do No Harm Process

Approved Electronically by:

Gayla F. Walden, PRINC DIRECTOR
SPACE INNOVATION DIRECTORATE
ADVANCED DEVELOPMENT & PLANNING DIVISION
DEFENSE SYSTEMS GROUP

Cognizant Program Manager Approval:

Mark P. Jelonek, GENERAL MANAGER
ADVANCED DEVELOPMENT & PLANNING DIVISION
DEFENSE SYSTEMS GROUP

Aerospace Corporate Officer Approval:

Jay G. Santee, VICE PRESIDENT
STRATEGIC SPACE OPERATIONS
DEFENSE SYSTEMS GROUP

Content Concurrence Provided Electronically by:

Douglas A. Harris, PROJECT LEADER SR
STRATEGIC INITIATIVES
ADVANCED TECHNOLOGY AND CONCEPTS
DEFENSE SYSTEMS GROUP

SQ0302