AEROSPACE REPORT NO.
ATR-2023-01224

Adaptive Mission Assurance (AMA) – A Conceptual Guide for NASA Missions

February 16, 2023

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Prepared for:

NASA Goddard Space Flight Center
Headquarters Procurement
Greenbelt, MD 20771

Contract No. 80GSFC19D0011

Authorized by: Civil Systems Group

Foreword

NASA is well acquainted with and skilled in conducting Risk Class A Safety and Mission Assurance (SMA). Class A missions are characterized as having highly specific performance with an ultra-low risk tolerance for risk and mission failure. But space is rapidly changing, and the space enterprise is challenged to pursue faster more agile mission developments with fewer resources and directed schedules. To meet this demand mission development teams face accepting more risk and trading performance within strict cost and schedule constraints. In responding to this challenge, The Aerospace Corporation has evolved the Adaptive Mission Assurance (AMA) approach.

The benefit of an "adaptive" approach is most realized for smaller Research and Development (R&D), or Science and Technology (S&T) demonstration missions constrained by significantly smaller budgets and directed schedules. The challenge for these "risk tolerant, constraints-driven" missions is how to identify the most valuable mission assurance tasks that will fit within strict budgetary and schedule constraints for "gracefully" accepting risk that still achieves an agreeable expectation of mission success. AMA can respond to this challenge with little to no impact to team staffing or existing workload. This conceptual guide introduces AMA as a potential implementation for NASA Risk Class D and Sub-Class D missions.

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1. Introduction

NASA is well acquainted with and skilled in conducting Risk Class A Safety and Mission Assurance (SMA). Class A missions are characterized as having highly specific performance with an ultra-low risk tolerance for risk and mission failure. The priority for these missions is to eliminate risk as much as possible to achieve the highest probability of success. Consequently, Class A missions will trade on cost and schedule to achieve the highest probability of success.

Class D and Sub-class D missions, however, are constraints-driven. These missions are typically more risk tolerant such as Research & Development (R&D) or Science & Technology (S&T) demonstrations. They are typified by uncertainty, change, evolving outcomes, limited resources, and directed schedules. Consequently, constraint-driven missions must strive to meet a prescribed cost and schedule while responding to uncertain change and still achieving "good enough" performance and risk that meets mission objectives.

Figure 1 illustrates a requirements-driven mission where strict performance, and risk requirements drive cost and schedule. These missions can adjust cost and schedule for achieving the lowest risk possible while delivering highly specified performance requirements.

Figure 1. Requirements-driven missions.

Figure 2 illustrates a constraints-driven mission where strict cost and schedule constraints drive performance and risk. These missions must tune performance and risk for staying within acceptable cost and schedule while still achieving mission objectives.

Figure 2. Constraints-driven missions.

AMA provides a value driven approach for selecting the highest value SMA tasks that will fit within cost and schedule constraints while still achieving an agreeable risk to mission objectives.

2. AMA Definition

Adaptive Mission Assurance is a value driven approach that incorporates "Agile" concepts for identifying and executing the highest value mission assurance tasks first within resource and schedule constraints. It is a "framework" that can enable NASA teams to optimize SMA tasks for risk tolerant (Class D and Sub-class D), constraints-driven missions. It is these smaller risk tolerant, constraints-driven missions that benefit most from AMA since mission development teams must choose the most valuable subset of SMA tasks that will fit within their prescribed constraints. By infusing a value driven discipline for organizing and prioritizing existing SMA tasks, it melds with the team's existing organization and communication tempo and relies on the existing collective intelligence and expertise of those using it.

AMA is a value-driven approach that tailors up its planned SMA tasks from a minimum set of mandatory requirements rather than tailoring down from a "gold" standard. It starts with the minimum "mandatory" requirements for areas such as Safety, Do-No-Harm, and other polices requiring compliance (e.g., orbital debris). It then employs an "Agile" mindset for building up from "discretionary" mission assurance tasks based on best value (i.e., not always the highest risk) for the unique mission context, risk tolerance, and limited resources and schedule. The most valuable tasks are delivered first which delivers the optimal set of activity within constraints. It then dynamically "adapts" for continuing to deliver highest value tasks first as the mission development "evolves" and "stuff happens."

Figure 3 illustrates a convenient method of visualizing how AMA tailors up SMA in contrast to tailoring down for Class A missions. Class A mission teams are charged with developing missions, with near 100% probability of success, that will deliver highly specified performance at ultra-high reliability and availability. In these Class A cases, the team must size their required "box" of budget and supporting resources for accomplishing the prescribed SMA. Class A SMA is usually planned in by tailoring down from a gold standard of requirements and then estimating the needed tasks, budget, and resources.

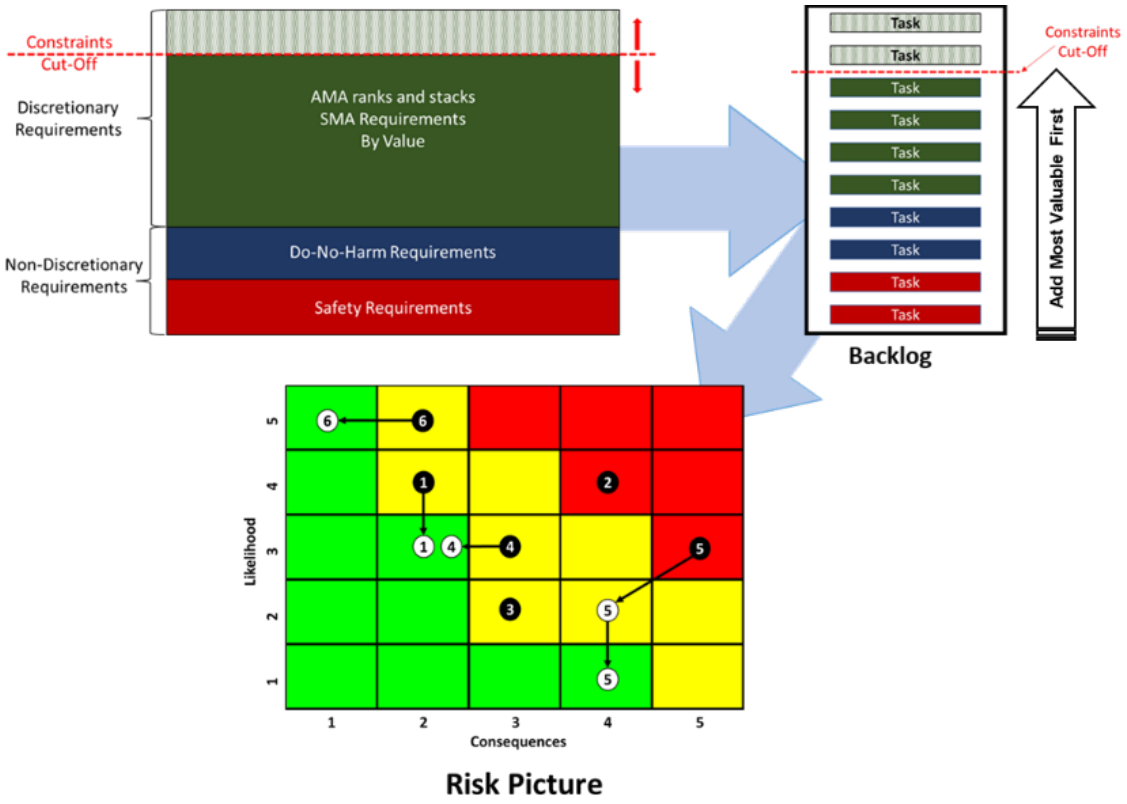


Figure 3. AMA tailors up SMA requirements.

For risk tolerant (Class D and Sub-class D), constraints-driven missions, teams are typically dictated a pre-sized "box" of budget and time. The team must strive to place the highest value SMA tasks providing the greatest return on investment in the box first. The AMA approach optimizes SMA tasks within resource constraints by prioritizing tasks that will provide the most bang for the buck.

For accommodating the uncertainty, change, learning, and discovery that are common for these types of missions, AMA iterates for continually assessing mission context, activity outcomes, new and realized risks, and other development emergences. The team may remove tasks from the box to make room for new, more valuable tasks based on continual observations and discoveries. Ultimately, it helps the team to burn down risk to a targeted residual that is agreeable and well understood by stakeholders creating a more realistic expectation of mission success from start to finish.

3. Agile Theory and the AMA Mindset

To fully understand AMA, it is helpful to understand the mindset and principles of Agile. The term Agile was formalized in the early 2000s as a mindset and guiding principles for bettering software development. It is an umbrella term for frameworks and practices that are based on the values and principles expressed in the Manifesto for Agile Software Development. The Agile Alliance describes Agile as "the ability to create and respond to change. It is a way of dealing with, and ultimately succeeding in, an uncertain and turbulent environment." (Agile Alliance, n.d.)

Figure 4 shows the Agile Manifesto (Agile Alliance, n.d.) which is easily applied to other disciplines and tasks such as project management and in this case, bettering mission assurance. Agile enables SMA to deliver the highest value first while responding to the uncertainty and change that characterizes Class D and Sub-Class D mission developments. As such, Figure 4 also shows a variation for mission assurance.

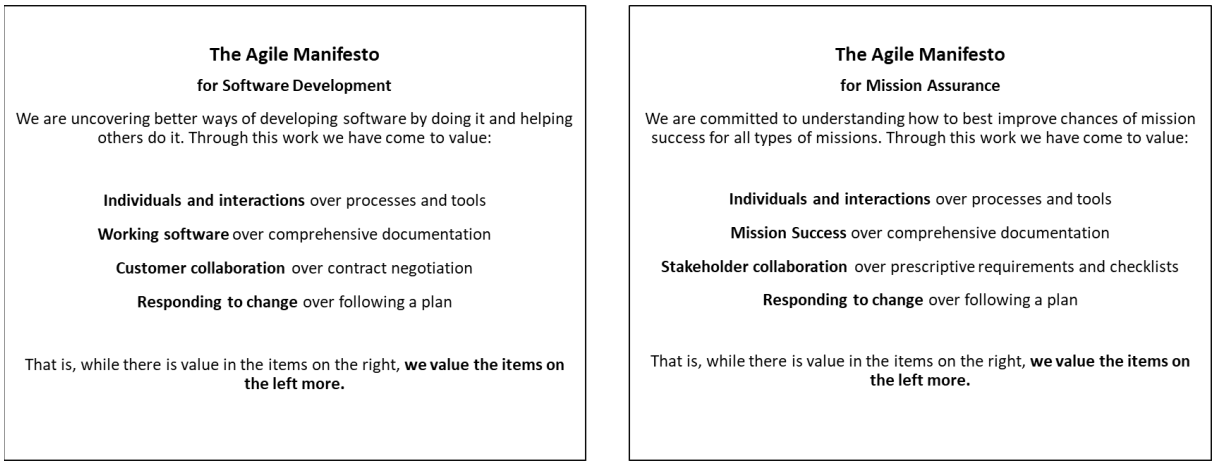


Figure 4. The Agile Manifesto.

The Agile Alliance also recommends 12 Agile principles (Agile Alliance, n.d.) behind the Agile Manifesto which are easily applied to mission assurance. Figure 5 shows these and the variation for Mission Assurance.

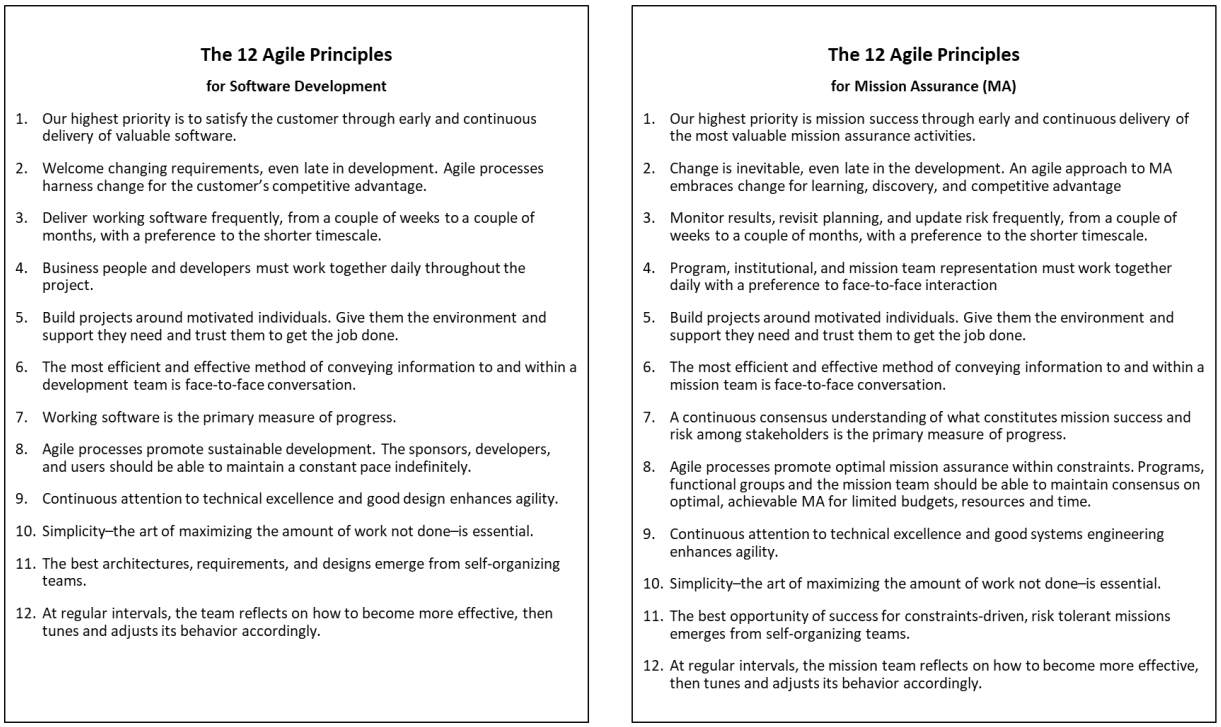


Figure 5. The 12 Agile Principles.

The AMA approach is derived from "Agile" concepts as defined in the Agile manifesto and principles. Like Agile, it relies on knowledge from experience, decisions based in observations, and lean thinking which strives to reduce lower value tasks while focusing on the essentials. That said, AMA is not intended as an additional layer of activity but rather a different way of approaching the same tasks that are already part of any mission development process. AMA employs a different mindset with several essential points of view that distinguish it from a typical mission assurance approach.

3.1.1 Failure AS An Option

"Failure" is not always the opposite of "Mission Success." Innovation, discovery, and learning require both success (little "s") and failure for achieving overall Success (big "S"). Failure is useful to learning since the whole reason organizations test, experiment, and demonstrate concepts and technology is to learn. Class D and Sub-class D missions are typically research & development, science and technology, or technology demonstrations for maturing technology on a roadmap to full operational use. Moreover, the advent of disaggregated constellations that deliver capability at the enterprise level can tolerate failure at the component level with minimal to no impact. Therefore, failure from "unknowns" inherent to innovative concepts and designs is an option if not an essential part of learning and discovery. A traditional mission assurance mindset that insists "failure is not an option" is still valid for those missions that are highly risk intolerant. Constraints-driven missions, however, must adopt a mindset that accepts risk and some probability of failure, yet still strives to optimize use of limited resources and schedule for gracefully doing so. The AMA approach is uniquely suited for doing this as well as maintaining stakeholder expectations of what constitutes mission success and managing their understanding of a continually evolving Risk Picture.

3.1.2 Value as the Primary Driver

AMA incorporates a value driven mindset. Requirements-driven, risk intolerant missions will typically allow the highest risks to drive which tasks receive the highest priority. Moreover, there are ample resources and time to burn down risks to very low residual. Constraints-driven missions, however, must allow value to determine which tasks will deliver the most "bang for the buck" to mission success. Value of an activity is measured by its projected risk reduction or impact to mission outcome divided by its effect on the project's highly constrained resources, cost, or schedule. Recall the analogy that constraints-driven missions are given a "pre-sized" box with limited capacity. Teams will want to place the most valuable tasks in the box first. Because these missions tend to be more risk tolerant, there is flexibility to favor the more valuable tasks versus the most risk mitigating tasks. It is not uncommon to favor an affordable mitigation of a lesser risk over a costly mitigation to a higher risk. It may prove more favorable to accept a lesser probability of achieving mission success over the certainty of failure should the project violate constraints resulting in project cancellation or missing a rideshare opportunity.

3.1.3 Embrace Simplicity and Change

Simplicity is the art of maximizing the amount of work not done. Constraints-driven missions should seek to avoid duplication by leveraging project management, systems engineering and developer processes that are already in the value chain of mission development. They should favor documentation that leverages "operative" artifacts maintaining an understanding of risk and risk mitigation but remembering that the main point of mission assurance is to improve the chance of mission success, not to document risks. Requirements lists and formal data deliverables are no substitute for working closely with stakeholders to discover what the mission needs to do, and how to best help it succeed. A formal plan typically only survives its first engagement so it must not be too rigid to accommodate changes in priorities, resources, risk, and emergent issues. Change is inevitable, even late in mission developments. An Agile approach embraces change for learning, discovery, and competitive advantage. As such AMA pursues a continuous consensus understanding of what constitutes mission success and risk among stakeholders. It requires continuous attention to technical excellence and good systems engineering for promoting the optimal mission assurance response within constraints. Mission assurance is anything that contributes to mission success.

3.1.4 Small Experienced Teams

Small, well experienced teams offer the best opportunity of success for constraints-driven, risk tolerant missions. Resist the temptation to assign less experienced people. It is important that teams consist of seasoned experts for making the hard decisions on where to trade performance and risk for cost and schedule. Smaller missions with their shorter mission development life cycles do offer great learning and training experience but make sure there is sufficient expertise to manage the development and provide mentorship. The agility to innovate, learn, and adjust to uncertainty also relies on shorter decision cycles. Consequently, a smaller team that shares a mutual understanding of the issues in the context of what constitutes mission success is essential. SMA representatives should be tightly integrated with the decision making of the core team working togethering daily while representing their unique program and technical authority accountabilities. It is also important that the mission team, at regular intervals, reflects on how to become more effective, then tunes and adjusts its behavior accordingly.

4. The AMA Sprint

AMA operates in short Agile "Sprints" or fixed duration cycles. Sprints align the steps of AMA with the tempo of the existing mission development. Sprints are typically short in duration (2 – 4 weeks but no more than 2 months) and cycle multiple times between the milestones of a mission development. AMA is intended as an infused discipline to existing mission development activity and events to avoid adding additional work. For example, timing sprint events to existing team meetings such as periodic IPT or risk boards is ideal. Figure 6 shows two views of a single Sprint. The first shows a Sprint with its supported Artifacts (Backlog and Risk Picture) and supporting Events (Planning, Review, and Retrospective). The second is a functional view showing the steps of AMA mapped into each event. These are discussed later in more detail.

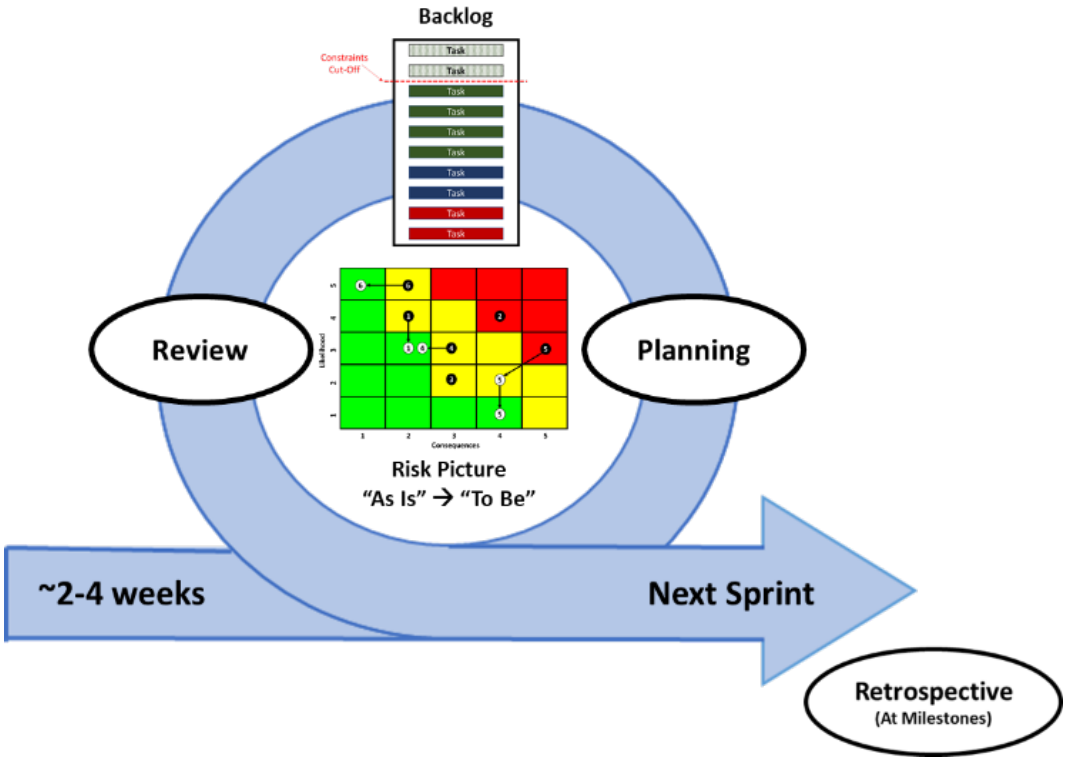


Figure 6a. The AMA Sprint (events view).

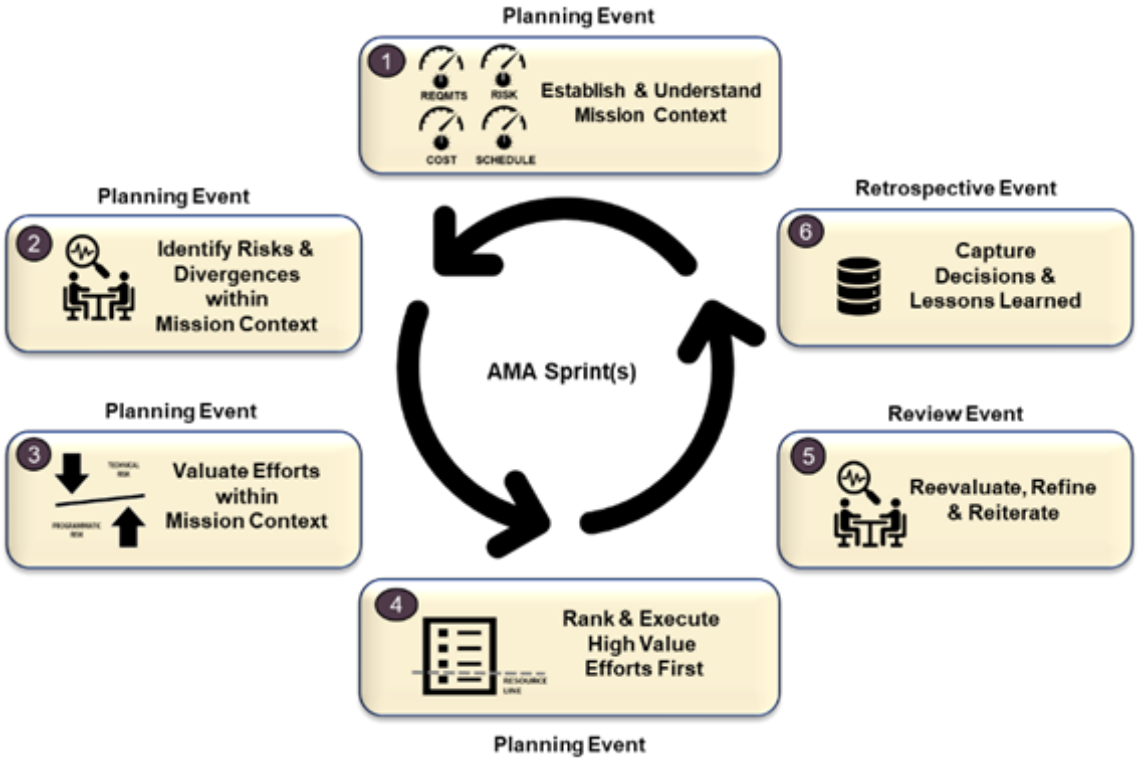


Figure 6b. The AMA Sprint (functional view).

Figure 7 shows how multiple sprints relate to mission milestones. Rapid turns of the sprint provide the agility for responding to changes, new risks, and other emergences encountered during the mission development.

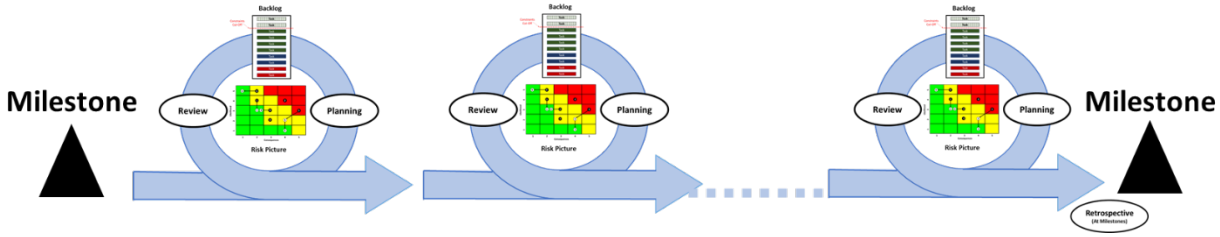


Figure 7. AMA operates as short sprints.

The purpose of the sprint is to evolve a dynamic AMA Backlog (also referred to herein as the Backlog) of tasks that are prioritized according to their value (i.e., not always the highest risk). The Backlog authorizes which tasks the team will work and is analogous as a dynamic Mission Assurance Implementation Plan (MAIP). The planned tasks of the Backlog, in turn, will evolve a Dynamic Risk Picture (also referred to herein as the Risk Picture). The Risk Picture describes the "As Is" risk and the "To Be" residual risk at some milestone in the future (e.g., launch). The Risk Picture evolves along with the Backlog of SMA tasks as affected by the Planning and Review Events within each sprint.

For those familiar with Agile sprints in software development, it is important to note that the product of each sprint is an evolution of the Backlog and its resulting Risk Picture; not the product of the Backlog tasks themselves. Tasks are typically in a waterfall schedule with durations that are almost always longer than the duration of a sprint. Moreover, they do not always begin within the sprint they are planned. So,

each Sprint simply adjusts the task Backlog and the resulting Risk Picture across the lifecycle as the mission develops, learns, and changes.

Lastly, Sprints provide a convenient and effective means for managing stakeholder expectations throughout the mission development life cycle of what is optimal within resource and schedule constraints.

5. AMA Team and Roles

There is a common misconception that risk tolerant, Class D and Sub-Class D missions can get by on less experienced project managers and engineers. The opposite is true in that constraints-driven, risk tolerant missions require more seasoned team members acquainted with mission development for making the hard decisions on what is good enough and maximizing the amount of work not done. It is true that these missions provide an excellent opportunity for cultivating new talent but only if augmented with more experienced practitioners. A smaller seasoned mission team has the general experience for identifying when and where more specific subject matter expertise is required. Having ready access to a diverse body of subject matter experts possessing specific knowledge, tools, and methods (e.g., thermal, structures, etc.) is essential. NASA Centers typically possess subject matter expertise. The challenge, however, could be getting agile access to the right expertise, when and where they need the support.

AMA leverages the existing team structure for missions that consist of representation from both NASA programmatic and institutional authorities involved in the business of mission development (see Figure 8). The core team for AMA decision making consists of the project manager, project systems engineer, safety and mission assurance lead, and representation from developer(s) performing the actual design and development of systems and supporting operations for achieving mission objectives.

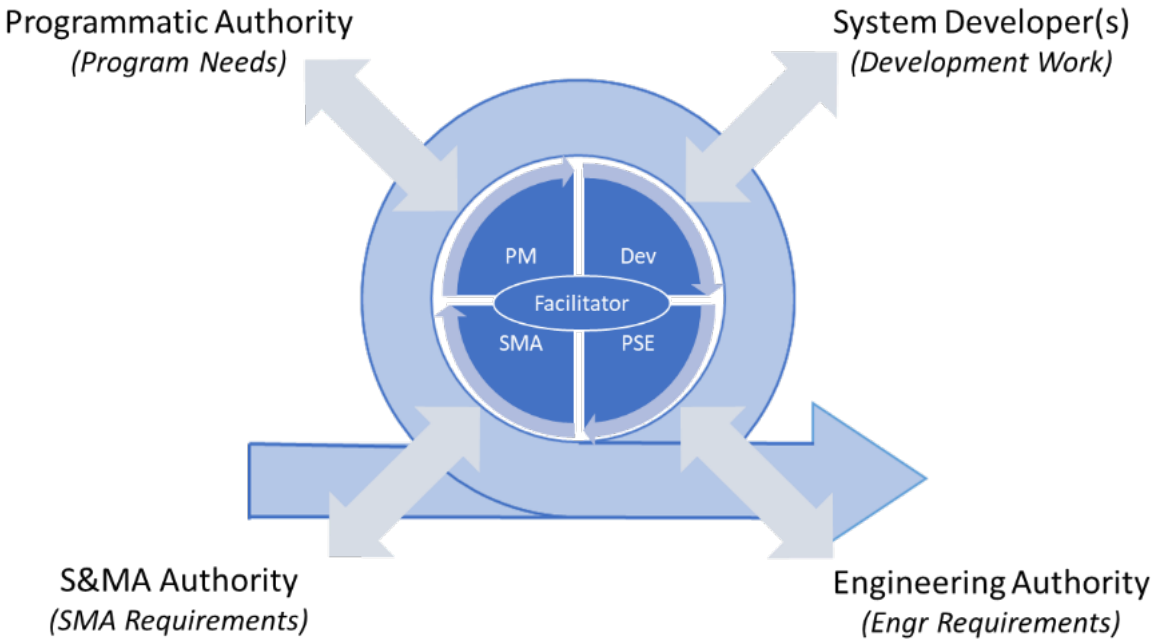


Figure 8. Core team and stakeholders.

Additionally, and key to the success of AMA is the Facilitator whose role is to ensure proper incorporation of AMA methods and artifacts and that they leverage existing functions with minimal addition of work.

5.1.1 AMA Facilitator

The AMA Facilitator is the only unique role for the AMA approach. This is role is the equivalent of a scrum master for those familiar with Agile software development methods. These individual conducts the workings of each Sprint and ensures that the team understands and adheres to the AMA approach in theory and practice. The sprint facilitator is accountable for the team's effectiveness in conducting each sprint and works to improve the team's practices within the AMA approach. Ideally, this individual is independent of participating in the development decisions freeing them to lead and guide the process of each sprint. That said, the facilitator can be a dual role for any of the core members such as the Project Manager (PM), Project System Engineer (PSE), or SMA Lead. But it is critical that a dual functioned Facilitator is experienced in the AMA approach and maintains a clear delineation of their roles during sprint execution.

AMA Facilitators support the Project Manager (PM) by facilitating stakeholder (e.g., Principal Investigator(s), Program, Mission Directorate(s), etc.) collaboration for defining mission context:

- Defining the "story" of what constitutes mission success and the risk posture
- Deriving prioritized goals and objectives, assumptions, and constraints
- Facilitating stakeholder collaborations as needed for changes in mission context

AMA Facilitators support the mission development team by:

- Facilitating the conduct of each sprint
- Fostering cross-functionality between project management, engineering, and mission assurance
- Assisting the team for defining clear and concise Backlog items
- Facilitating valuation exercises for prioritizing the Backlog
- Identifying and removing impediments to sprint team progress
- Ensuring positive and productive sprint events within the time established by the sprint tempo

AMA Facilitators may also support Technical and Programmatic Authorities in several ways to include:

- Leading, training, and coaching the organization in AMA theory, practice, and adoption
- Planning and advising AMA implementations within the Center or Mission Directorate

5.1.2 Project Manager (PM)

The PM is the mission development lead assigned by the responsible NASA Center. The AMA approach does not impose additional roles or responsibilities to the PM beyond that of a traditional project and MA approach. It does, however, frame those traditional roles and responsibilities into AMA sprints. So, in context of a typical sprint, the PM is responsible to:

- Lead the mission development team for decisions during sprint events

- Provide approval and prioritization and authorization of tasks on the Backlog

- Coordinate changes that affect consensus expectations of stakeholders and, with the assistance of the AMA facilitator, reestablish a consensus on the revised expectations

5.1.3 Project Safety & Mission Assurance Lead (SMA Lead)

The Project SMA lead is designated by the responsible NASA Center and assigned supporting resources. The AMA approach does not impose additional roles or responsibilities to the SMA Lead beyond that of a traditional project and MA approach. It does, however, frame those traditional roles and responsibilities into AMA sprints. So, in context of a typical sprint, the SMA Lead is responsible to:

- Represents safety and mission assurance requirements as they are properly valuated, dispositioned and prioritized within the mission context
- Accomplishes tailoring of S&MA requirements for risk class, constraints, and mission context during mission formulation
- Seeks to leverage PM or engineering tasks or SMA specific tasks on the Backlog.
- Coordinates the use of SMA subject matter expertise and support as authorized on the Backlog

5.1.4 Project Systems Engineer (PSE)

The PSE is designated by responsible NASA Centers and assigned supporting resources. The PSE represents all engineering tasks including those responding to safety and mission assurance requirements on the Backlog. The PSE enlists and coordinates the use of NASA Center engineering resources as authorized by the Backlog.

5.1.5 Developer(s) Lead

The Developer(s) Lead represents the work and interests of the Developer(s). Developer(s) are those organization(s) that perform the actual work of delivering systems, tools, data, information, and procedures during the mission design, development, integration, testing, and execution. The Developer(s) Lead represents all development tasks and interests during Sprint Events. Developer(s) can consist of either NASA resources, development contractors, or both.

6. Sprint Artifacts

There are two main artifacts upon which the sprints of the AMA approach operate and affect (See Figure 6). The first is the AMA Backlog which is a value prioritized register of SMA tasks for potential execution depending on the resource and time constraints. The second is the Dynamic Risk Picture resulting from SMA tasks the team chooses to implement because of their priority within resource and time constraints. Although these artifacts are specifically defined for the AMA approach, they are not unique from typical developments. In other words, the Backlog is simply an Agile method for establishing and maintaining a Mission Assurance Implementation Plan (MAIP) plan along with its resulting Risk Picture.

6.1.1 AMA Backlog

The AMA Backlog is a list of potential tasks prescribed by SMA requirements and phased across the lifecycle of the mission development. Time and resource constraints will determine the cut-off for which tasks can be executed within their lifecycle phase. Keeping with the bottom-up approach, the initial list begins with those tasks driven by mandatory requirements for human safety, Do No Harm (DNH), and other mandatory policies. The remaining requirements generate "discretionary" tasks which are prioritized by their value within the mission context. Figure 9 shows the process for building the initial Backlog.

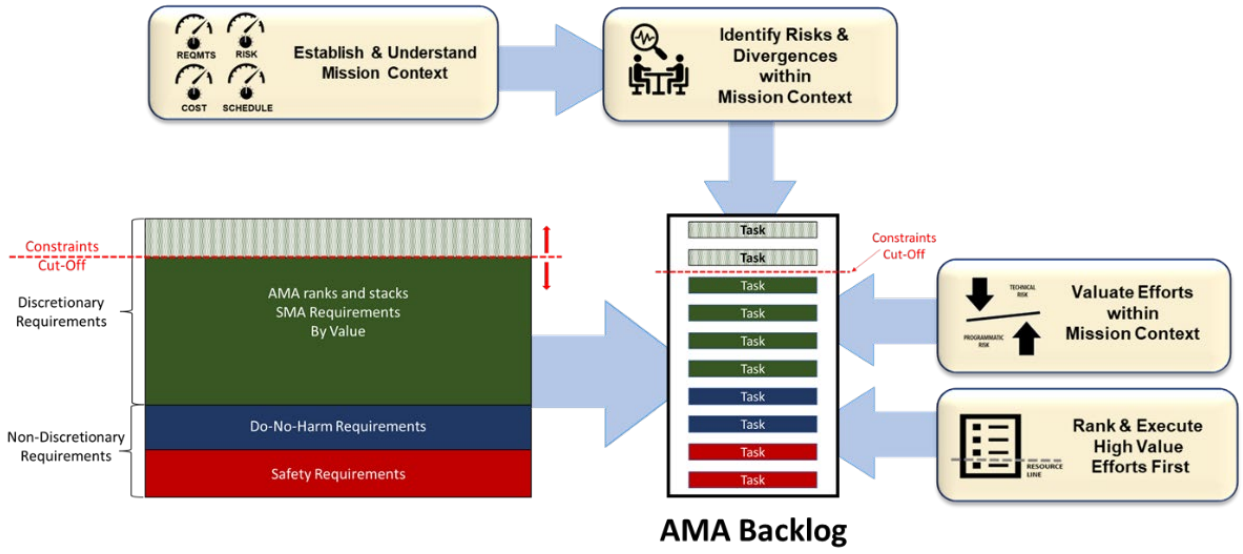


Figure 9. Building the AMA backlog.

The first and most important step for any mission development is to reach consensus on mission context. Mission context includes what the team constitutes as mission success captured as a story and what the mission is trying to accomplish as mission objectives. Context also includes the driving resource and time constraints as well as the risk tolerance. This gives the team the context for identifying initial risks and then prioritizing the discretionary tasks on the Backlog. Tasks are prioritized on the Backlog based on their "value" as seen in Figure 10.

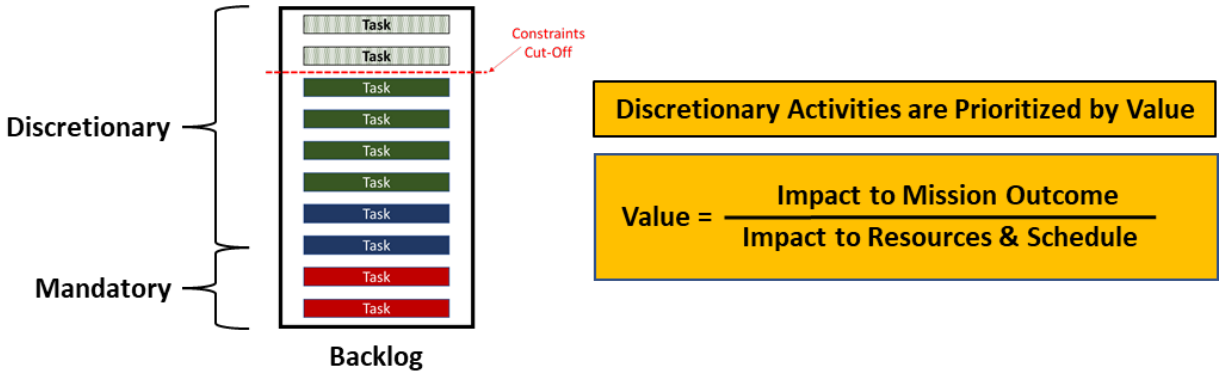


Figure 10. Prioritization of discretionary tasks.

Success for constraints-driven missions is contingent upon both achieving the mission objectives as well as meeting resource and time constraints. Therefore, value is defined as the impact an activity has on mission outcome divided by the impact it will have on resources and schedule. This means that an activity for reducing a high "red" risk may possess very low value if the impact to resources or schedule is too high. Impact is measured using "story points" determined by a consensus method called "valuation poker" described in the Planning Event section. Figure 11 shows an excerpt for an example AMA Backlog.

Ref	Activity	Mission Impact (Story Points)	Cost Impact (Story Points)	Value Score (Ratio)	Disposition	SMA Requirements	
						SMA Area	Reference
39	Safety Data Package	…	…	…	Mandatory	System Safety	3.3.5
92	Contamination Control Plan	…	…	…	Mandatory	Contamination	9.1
83	ODAR and EOMP	…	…	…	Mandatory	System Safety	3.3.8
3	Limited Life Items	10	2	5	Implement	Reliability	4.3
2	Printed Wiring Board (PWB) Test Coupons	2	5	0.4	Discretionary	Workmanship	6.5
86	Parts Radiation	2	10	0.2	Discretionary	EEE Parts	7.6

Figure 11. Example AMA backlog.

Constraints-driven means there is a resource and schedule "ceiling" or "cut-off." The team must determine where to "draw the line" on the Backlog so that only those cumulative items whose total cost or schedule impact fall within the cut line are implemented. Because they are prioritized by value, the most valuable items are implemented first. For those familiar with Agile software development, it is important to note that unlike Agile software development, SMA tasks are not started and completed within sprints. Sprints only evolve the Backlog and the Risk Picture. Tasks in the Backlog are accomplished in their appropriate time as shown in Figure 12.

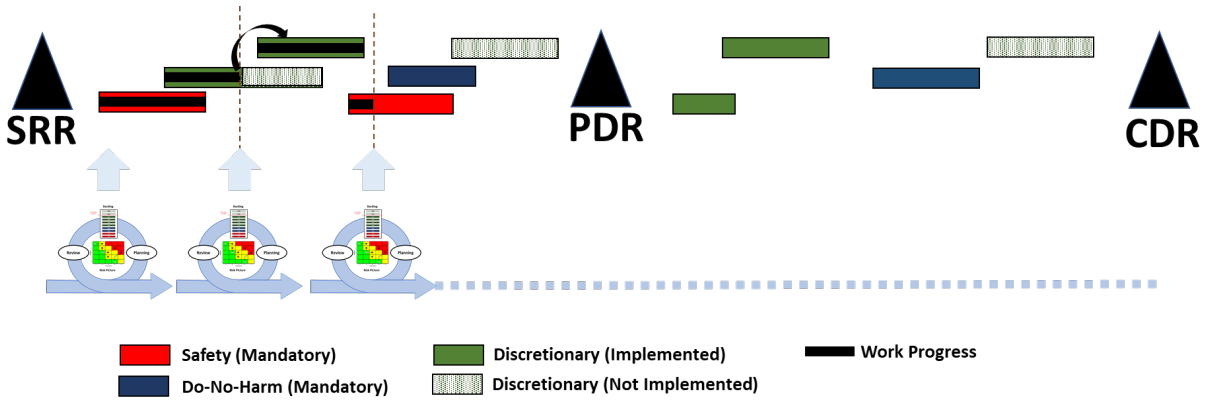


Figure 12. Sprints evolve the AMA backlog authorizing scheduled tasks.

Note that since the Backlog is dynamic, tasks for the current phase can change from sprint-to-sprint shifting to higher value tasks based on changing mission context or situation; even abandoning already active tasks as shown in the figure. In the same way, planned tasks for future phases can change from sprint-to-sprint as well.

Each sprint evolves the Backlog which in turn affects and evolves the Risk Picture depending on which tasks are above the cutline and authorized for implementation.

6.1.2 Risk Picture

The AMA Backlog affects a Dynamic Risk Picture based on items that are authorized for implementation by the AMA team (See Figure 13).

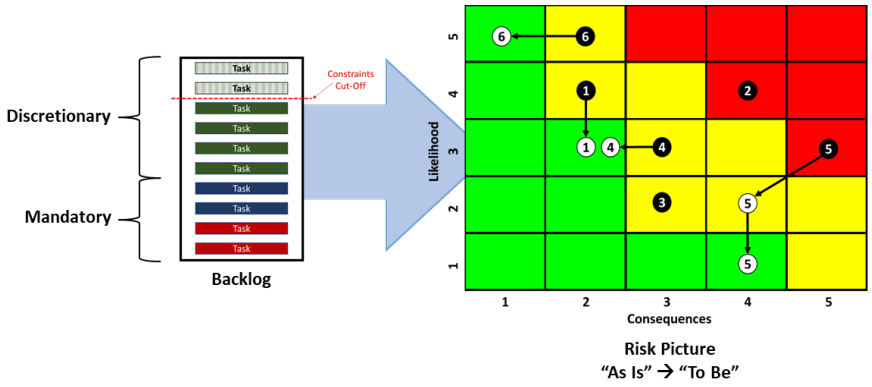


Figure 13. AMA backlog evolves a dynamic risk picture.

Tasks on the Backlog (some driven by SMA requirements and some by emergences) can identify, analyze, or mitigate risks. Initial risks along with emergent risks identified during the development lifecycle are shown using traditional methods (e.g., 5x5 Matrix). These are the "As Is" risks that tasks on the Backlog can mitigate or burn down risk producing "To Be" risks at future milestone(s) or final Certification of Flight Readiness (CoFR). Figure 13 shows a method by which risks in black represent the current or "As Is" risk with arrows pointing to white circles representing future "To Be" residual risks. Some may have multiple progressions throughout the lifecycle. For example, Risk 5 could be a risk that is mitigated from a 3x5 to a 2x4 via analysis and subsequently mitigated from 2x4 to 1x4 via testing. Each activity, analysis, and testing could be a separate item on the Backlog (one in design and one in I&T). If

the AMA team determines in a later Sprint that they cannot implement testing due to higher value tasks, it is understood that Risk 5 will remain as yellow (2x4) risk through CoFR.

7. Sprint Events

There are three Sprint Events: Planning, Review and Retrospective (see Figure 6). Each Sprint begins with a Planning Event and completes in a Review Event. Retrospective Events are held at each development milestone but can be more frequent if desired. The Planning event is focused on establishing and maintaining the Backlog along with its affect to the Risk Picture. The Review Event is focused on active task outcomes, divergences that emerge during the mission development or changes in mission context. Although these events are specifically defined for the AMA approach, they are not unique for typical developments. For example, the Planning Event is simply an Agile method for establishing and maintaining a Mission Assurance Implementation Plan (MAIP) plan along with its resulting Risk Matrix. The Review Event is hopefully something that mission teams are already conducting on a routine basis for status of mission assurance tasks, their outcomes, and affect to mission risk and readiness.

The three events of a Sprint incorporate six (6) iterative functional steps. Figure 14 shows these steps which coincide and occur within the Events of each scheduled Sprint. The Planning Event incorporates Steps 1-4. The Review Event incorporates Step 5. The Retrospective Event incorporates Step 6. Each Functional Step is led by the Project Manager and facilitated by the AMA Facilitator within its corresponding Sprint Event.

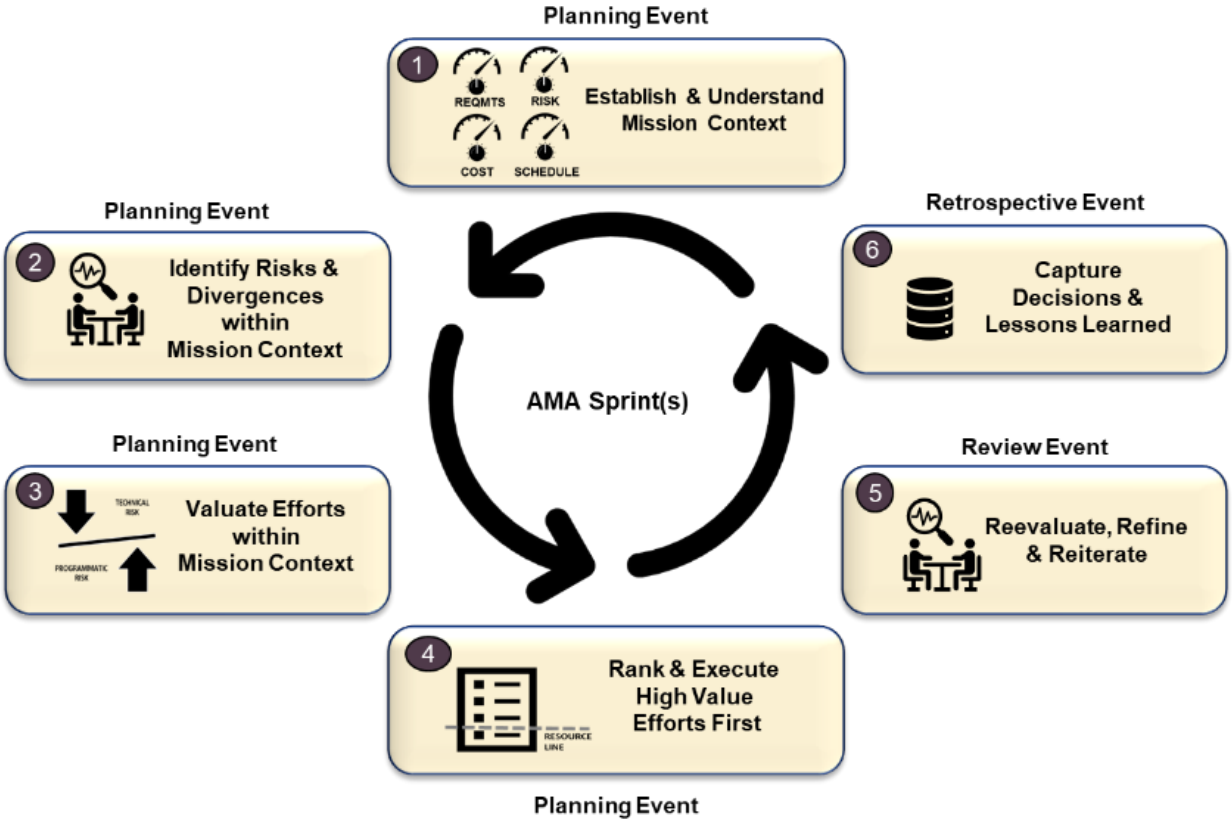


Figure 14. Functional steps within AMA Sprints.

7.1.1 Planning Event

Each Sprint begins with a Planning Event. This event can and probably should get incorporated with an existing routine tag up of the mission development team. The purpose of the Planning event is to establish

and subsequently maintain the Backlog along with its effect on the Risk Picture. Figure 15 shows how the Backlog and Risk Picture are built up during the first Planning Event and then maintained during subsequent sprints.

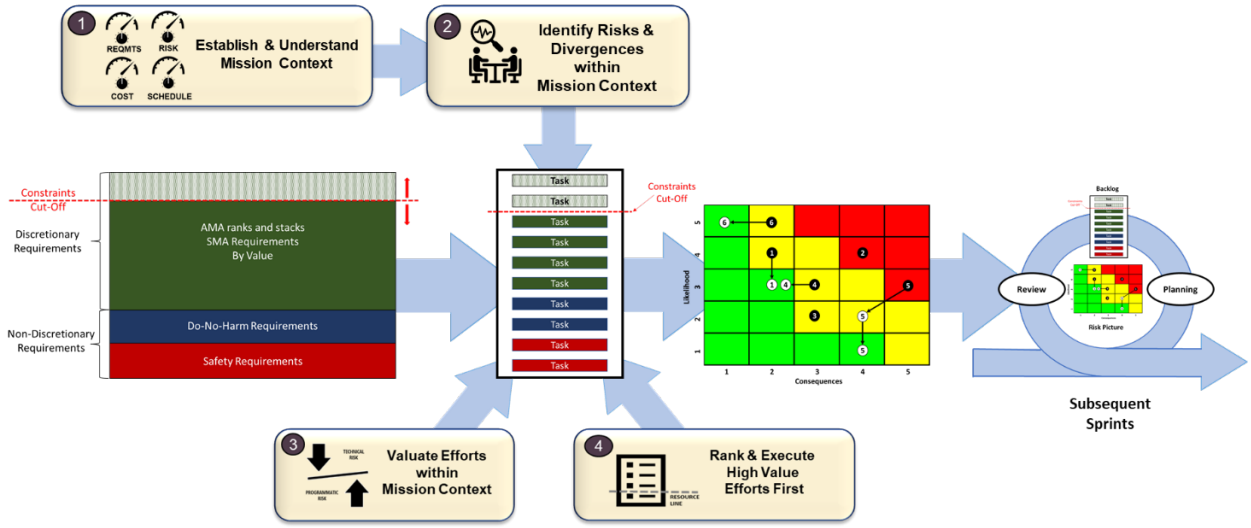


Figure 15. Planning event(s): building and maintaining AMA backlog and risk picture.

Step 1: Establish and Understand Mission Context.

During the first sprint Planning Event(s), the team must establish the "mission context" by achieving consensus among stakeholders on what constitutes mission success (e.g., a prioritized set of mission objectives with driving assumptions) and understanding mission constraints (e.g., cost, schedule, or SWaP). Opinions among stakeholders and developers will often differ so it is imperative that consensus is achieved and captured for regular revisits during subsequent sprints. The team may also want to reach consensus on minimum performance requirements, and what is negotiable if trades become necessary.

The team and stakeholders should reach consensus on an initial risk posture. Examine the mission objectives and complexity to determine if there is inherent risk to mission success due to resource and time constraints. It may be that mission expectation or complexity is too high for the given constraints rendering the mission unachievable; better to know that now than later. New and unproven concepts or technologies will carry their own risk and the team must acknowledge the possibility of failure or trading assurance for other desirable mission attributes.

Capturing consensus on these contextual items (e.g., Ground Rules and Assumptions (GR&A)) gives the team a reference for measuring value and making decisions later. The team will revisit this as necessary as part of future sprints to ensure that mission context has not shifted which would require another facilitated consensus.

Step 2: Identify Risks & Divergences within Mission Context.

Early on during the first Sprint, the team will want to perform a "blitz" risk assessment of the mission based on mission context. This will provide the initial baseline of "As Is" risks to the mission. This initial assessment is more comprehensive in its breadth than in its depth. The team should consider repeating a blitz risk assessment at each milestone. These comprehensive assessments are an excellent time for the team to include subject matter experts as appropriate. The team should use its existing risk management process for collecting and updating any new emergent risks during subsequent sprints.

Initial risks along with emergent risks identified during the development lifecycle are shown using traditional methods (e.g., 5x5 Matrix). These represent the "As Is" state of risks that tasks on the Backlog will later mitigate or burn down producing "To Be" risks at some future milestone(s) or at final Certification of Flight Readiness (CoFR). Figure 13 showed a method by which risks in black represent the current or "As Is" risk with arrows pointing to white circles representing future "To Be" residual risks once they are mitigated by tasks on the Backlog.

Step 3: Valuate Efforts within Mission Context.

Equipped with mission context and initial risks, the team can begin to assess which of the efforts are appropriate given their value for improving mission success. The first Sprint Planning Event will build up the initial Backlog of tasks based on their value to achieving mission success within constraints. Going forward, future Sprint Planning Events will groom the Backlog based on any emergent changes or divergences.

NASA Directorates and Centers may already maintain tailored Mission Assurance Requirements (MAR) documents suitable for building up an initial Backlog. For Example, the Science Missions Directorate (SMD) and Goddard Space Flight Center (GSFC) have published MARs that are tailored for Class D / Sub-class D missions. However, there is no one size fits all. Consequently, teams must determine which requirements are represented in their Backlog based on task value.

The first tasks that are added are those responding to mandatory requirements such as Safety, Do-No-Harm, and other policy demands. The team will then add upon the mandatory tasks those discretionary tasks responding to requirements that are appropriate for the mission type and context. For reference, Appendix A provides an example compilation of potential requirements categorized as mandatory and discretionary for reference. Additionally, The Aerospace Corporation has published guidance on the process and checklist for Do-No-Harm requirements if appropriate (Aerospace TOR-2016-02946, "Rideshare Mission Assurance and the Do No Harm Process").

Once the Backlog is populated, the team can now valuate each discretionary task for prioritization. Value is determined by the impact a task has on mission outcome divided by the impact that task has on resources and schedule (See Figure 9). Impact is measured in "story points" which provides a means for

relative comparison. Note that this is a highly subjective approach that favors "relative predictions" over "perfect estimations." Relative value of tasks is all that is needed for prioritizing tasks.

There are several methods for scoring tasks using story points but one of the most popular within the Agile software community is a technique called "Planning Poker™." Planning Poker™, a registered trademark of Mountain Goat Software, LLC, provides a game like method for scoring tasks based on their impact to the mission outcome and their impact to resources and time. It also leverages team knowledge, fosters discussion, and drives consensus. Planning Poker™ uses playing cards that resembles a "Fibonacci" sequence of numbers representing story points (See Figure 16).

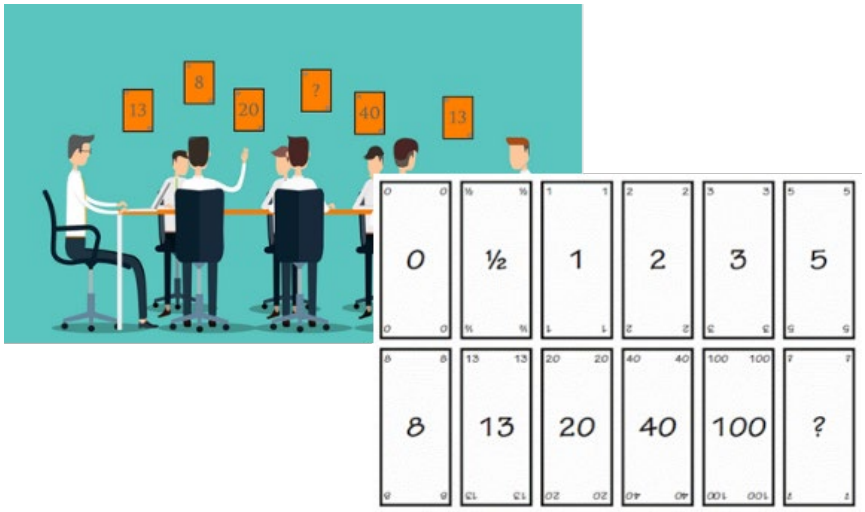


Figure 16. Valuation using Planning Poker™.

The team reviews, considers and discusses each discretionary Backlog task within the mission context before voting on impact. Everyone should get a chance to share their view before voting. Voting involves each member privately selecting a number and revealing that card at the same time as other members on the team. If the points are close for selecting a score, then consensus is achieved. If they are diverse or there are outliers, then the team needs to discuss the task further allowing dissenting votes to express their reasoning for higher or lower scores before voting again. This continues until consensus is achieved upon a single number. This is accomplished for both the impact a task has on assurance to the mission and for the impact that the task will have on resources and time (schedule). Voting can also occur electronically for distributed teams. Consensus scores are annotated in the Backlog with the tasks for determining the score "story point" ratio of impact to mission outcome divided by impact to resources and time (see Figure 10). This ratio allows the team to determine which tasks possess the most bang for the buck value for prioritization. Tasks with large impact to outcome and minimum impact to resources and time will score high for value. Tasks for burning down red risks with large impacts to resources and time will score lower; and can prove prohibitive if the cost is simply too high.

Step 4: Rank and Execute High Value Efforts First.

Recall that for constraints-driven missions, teams are dictated a pre-sized "box" restricting their resources, budget, and schedule. Consequently, there is a "cut line" for determining which tasks from the

Backlog the team can implement within those constraints. The team will want to rank tasks based on their value from the Valuation exercise and execute the highest value tasks first.

During first Sprint Planning Event, the team will make rough order resource and time estimations starting with the most valued tasks first. Rough order estimations are good enough and it is not necessary to do this for all the tasks on the Backlog. Continue these rough estimations for the higher value tasks until the "cut line" for constraints is reached. Tasks within the cut line are authorized for execution at their appropriate time within the lifecycle phase (see Figure 11). Items above the cut line are not authorized for execution unless something changes. Dispositions for discretionary task implementation are tracked in the Backlog (See Figure 10).

This establishes the baseline of tasks that are planned across the lifecycle recognizing that values can change with new emergent risks and issues. Hence, subsequent Sprint Planning Events will revisit mission context, new risks and emergent issues, and any changes in the predicted cost and schedule of a task as the mission development progresses. This may require another round of valuation (e.g., Planning Poker™) for new tasks or for changes to existing tasks. Reprioritization of tasks according to their value and relative to constraints my cause changes to the baseline of tasks across the lifecyle (see Figure 11).

Lastly, the team will assess the "To Be" burndown of risks resulting from tasks currently authorized for execution on the Backlog. Figure 12 showed a method for capturing the current "As Is" risks as solid black circles with arrows pointing to the "To Be" residual risks as white circles. Some risks may have multiple burndown progressions if there are multiple Backlog tasks at different points in the lifecycle. The resulting Risk Picture is dynamic and evolves with changes in the Backlog which in turn evolves with changes in the mission development. For example, if the team determines in a later Sprint Planning Event that a task is no longer possible within constraints due to an emergent need that adds a higher value task then the team should update the "To Be" risks on the Risk Picture accordingly.

Planning Events will continue for each new Sprint revisiting mission context for changes such as changes to mission objectives or stakeholder expectations or changes to project constraints. The team will continue to monitor for new risks or other emergent issues that require changes to the "As Is" Risk Picture as well as grooming of the Backlog for affecting the "To Be" residual risks. It is essential that the team keep stakeholders apprised of progress and changes on a mutually agreeable rate. If there is an impasse on agreement regarding acceptable risk, then the team can either reprioritize the Backlog to improve the risk (although not optimal) or request additional resources or time to relax constraints. By the way, this exercise creates a better narrative for requesting added resources if that is pursued.

7.1.2 Review Event

Whereas Planning Events are focused on the Backlog, Review Events are focused on the outcome of authorized backlog tasks, emergent risks and issues, and any other changes in mission context. Review Event results will inform the next Sprint Planning Event. Review Events can easily leverage other project status meetings for accomplishing their purpose. The Review Event involves Step 5 which reevaluates, refines, and reiterates.

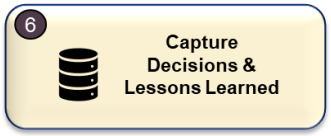
Step 5: Reevaluate, Refine, and Reiterate.

During the Review Event, the team will review active task outcomes, mitigation results, and any new risks, divergences, or issues. Some tasks may prove cheaper than expected allowing for additional tasks to be added to the Backlog during the next Planning Event. Some tasks may come in more expensive requiring adjustments as well. If the Review Event reveals emergences that require subject matter experts (SME), then consider inviting those SME to the next Sprint Planning Event to participate in discussion and voting. Additionally, the team should revisit mission context to determine if there are any changes to mission objectives, cost and schedule constraints, or risk posture. Update the Risk Picture as necessary.

7.1.3 Retrospective Event

Retrospective Events have a different focus than Planning and Review Events focusing on the method of AMA and mission development; how they are working or not working. Retrospective Events can occur at the conclusion of any Sprint but are most efficient and likely to be effective at mission development milestones.

Step 6: Capture Decisions & Lessons Learned.



Retrospective Events examine AMA and mission development roles, interactions, communication, and technique. The team discusses encountered problems and how they were (or were not) solved. Conclusions will result in actions for adjusting the AMA approach in subsequent phases and future mission developments.

This is also an excellent time to summarize decisions and lessons learned relative to the mission development lifecycle phase. Are there lessons learned for project management, systems engineering, mission assurance or any of the supporting functions such as acquisition, procurements, or legal that could benefit future mission developers. Consider incorporating the results of Retrospective Events with organizational bodies of knowledge or lessons learned.

8. Supporting Milestones and Mission Readiness

Figure 17 shows how Sprints deliver iterative states of the Backlog & Risk Picture for supporting mission milestones and readiness.

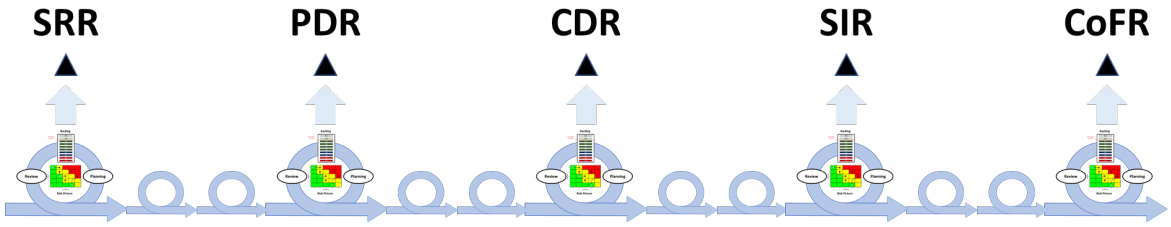


Figure 17. AMA support to milestones and mission readiness.

Sprints evolve the Backlog and Risk Picture based on mission context, divergences, and constraints enabling teams to report out the current situation at each of the mission development milestones. It reports the current "As Is" and "To Be" Risk Picture along with the supporting tasks to date captured in the Backlog. The Backlog also documents changes, decisions, and the going forward plan. The team can demonstrate that it has optimized activity by prioritizing those tasks that deliver the best value within constraints. Frequent collaboration keeps the evolving Backlog and Risk Picture in front of stakeholders and approval authorities so that they are not surprised at the milestone events. There is also a benefit to the mission development team since AMA coordinates new stakeholders or decision authorities during leadership or personnel turnovers.

Once the mission team reaches Flight Readiness Review, the To Be" risk picture at Flight Readiness Review has become the "As Is" residual risk supporting Certification of Flight Readiness (CoFR). Frequent collaboration has kept the Backlog and evolving Risk Picture in front of stakeholders and authorities so that no one is caught off guard or surprised by the resulting Risk Picture since the mission team has coordinated its evolution all along the way. This also guards against simple human nature of a willingness to accept risk early in the development giving way to an unwillingness to consider some probability of mission failure at CoFR. Ultimately, AMA has optimized SMA and other functional tasks for burning down risk to a targeted residual that is agreeable and understood by stakeholders for a more realistic expectation of mission success.

9. References

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[2] Agile Alliance. (n.d.). *The 12 Principles behind the Agile Manifesto* Retrieved January 25, 2023, from https://www.agilealliance.org/agile101/12-principles-behind-the-agile-manifesto/

[3] Goddard Space Flight Center (GSFC). (Aug 2016) SMall EXplorers (SMEX) Mission Assurance Requirements (MAR) Revision B, Mission Risk Classification - NPR 7120.5 Class D.

[4] NASA Science Mission Directorate (SMD). (Jan 2018) *Class D Tailoring/Streamlining Implementation Plan*.

[5] Read, A., Chang, P., Braun, B. Voelkel, D. (2016). *Rideshare Mission Assurance and the Do No Harm Process* (Report No. TOR-2016-02946-Rev A). The Aerospace Corporation.

[6] Schwaber, Ken and Ken Sutherland (Nov 2020). *The Scrum Guide, The Definitive Guide to Scrum: The Rules of the Game,* from https://www.scrum.org/resources/scrum-guide

Appendix A. Risk Class D Mission Assurance Requirements (MAR)

Appendix A provides an example of an initial compilation of potential requirements categorized as mandatory and discretionary for reference. No one size fits all, so teams must determine which requirements are best represented in their Backlog based on mission context and task value. NASA Directorates and Centers may already maintain tailored Mission Assurance Requirements (MAR) documents suitable as compilations for building up an initial Backlog. This listing was developed from the SMall EXplorers (SMEX) MAR published by Goddard Space Flight Center (GSFC) and the Class D Tailoring/Streamlining Implementation Plan published by the Science Missions Directorate (SMD).

Ref	SMA Area	Title	Requirement	Disposition
1.1	General	Safety and Mission Assurance Program	Developer shall implement Safety and Mission Assurance Program. Develop MAIP / Compliance Matrix (DID 1-1)	Mandatory
1.2	General	SMA Management	Developer shall designate an independent manager (i.e., not responsible for project costs and schedules other than those pertaining to assurance activities) and the functional freedom and authority to interact with all elements of the project to represent planning, execution, and status for assurance activities and deliverables to the project team.	Mandatory
1.3	General	Requirements Flowdown	Developer shall apply the applicable system safety and mission assurance requirements to subcontractors and suppliers to the extent necessary to ensure that the delivered product meets requirements.	Mandatory
1.4	General	Suspension of Work Activities	Developer shall direct the suspension of any work activity that presents a hazard, imminent danger, or future hazard to personnel, property, or mission operations resulting from unsafe acts or conditions that are identified by inspection, test, or analysis.	Mandatory
1.5	General	Surveillance	Developer shall grant access for NASA and NASA SMA to conduct an audit, assessment, inspections, or survey upon notice per the FAR providing documents, records, equipment, and a suitable work area within the developer's facilities as needed.	Mandatory
1.6	General	GMIPS	Government Mandatory Inspection Points (GMIPS): Project Team will apply an adaptive risk-based approach for evaluating which GMIPs are imposed on Developer(s). Developer shall support (TBD GMIPS) as requested. (TBD GMIPS) is any GMIP that the project team decides is necessary using an adaptive risk-based approach. Each GMIP is entered into the SMA backlog as a separate activity. Project PCB must approve any decision to not perform GMIPs listed below, and a waiver will be generated. Any reduction from the GMIPS listed below is also submitted to the MSFC SMAC/EMC for concurrence. a. Circuit Card/Hardware Assemblies - Final Solder / Pre-Conformal Coating and Staking b. Circuit Card/Hardware Assemblies - Post Conformal Coating c. Harness – pre integration (pre staking or potting) d. Unit/component, subsystem, and top-level assembly – witness final assembly e. Mechanical – final assembly and acceptance test f. Rework and repairs to flight hardware g. Test – TBD (addressed at time of contract)	Discretionary
2.1	Quality Mgmt	Quality Assurance Plan	Developer shall have a quality management system that meets the intent of SAE AS9100 Quality Systems - Aerospace - Model for Quality Assurance in Design, Development, Production, Installation and Servicing or ISO 9001 Quality Management System.	Mandatory

Ref	SMA Area	Title	Requirement	Disposition
2.2.1	Quality Mgmt	Nonconforming Products	The developer shall have a documented closed loop system for identifying, reporting, and correcting product nonconformances. The system shall ensure that the adequacy of corrective action is determined by audit or test, that objective evidence is collected, and that preventive action is implemented to preclude recurrence.	Mandatory
2.2.2	Quality Mgmt	MRB	The developer shall have a documented process for the establishment and operation of a MRB to process nonconformances, including the definitions of major and minor nonconformances. The developer shall appoint an SMA MRB chairperson who is responsible for implementing the MRB process and functional and project representatives as MRB members. The MRB shall include the Project CSO or designee as a voting member with approval authority on all major (repair and use as is disposition) MRBs involving procured hardware. The project government representative shall have access to the applicable documentation in advance of the scheduled MRB. The developer shall inform the Project of MRB actions (DID 2-1).	Mandatory
2.2.3	Quality Mgmt	Anomaly Reporting	Developer shall have a documented process for anomaly reporting and disposition. The process will establish an anomaly review board (ARB) whose membership shall include the CSO or their designee, as a voting member with approval authority for proposed actions on all major anomalies. The process shall require major anomalies to be submitted to the ARB and the government (DID 2-2). The developer shall report major hardware anomalies beginning with the first application of power at the component level, major software anomalies beginning with flight software acceptance testing and when interfacing with flight hardware, and major mechanical system anomalies beginning with the first operation. The developer shall assess the failure risk ratings and failure effect risk ratings for major anomalies (see DID 2-2 for criteria) and identify those that have a failure effect risk rating of 2 or 3 and a failure corrective action risk rating of 3 or 4 as a significant residual risk in the risk list. The process SHALL allow the developer to disposition minor anomalies with an appropriate subset of the ARB.	Mandatory
3.1	System Safety	System Safety Program	The developer shall document and implement a system safety program, support the ELV Safety Review Process as defined in paragraph 2.4 of NPR 8715.7 Expendable Launch Vehicle Payload Safety Program, meet launch service provider requirements, and launch range safety requirements.	Mandatory
3.1.1	System Safety	LSP-REQ-317.01, Launch Services Program (PPODs)	The developer shall implement LSP-REQ-317.01, Launch Services Program, Program Level Poly Picosatellite Orbital Deployer (PPOD) and CubeSat Requirements Document (for CubeSats launched on PPODs by LSP)	Mandatory (If applicable)
3.1.2	System Safety	Inhibits	The developer shall incorporate three (3) independent inhibits in the design (dual failure tolerant) if a system failure may lead to a catastrophic hazard. A catastrophic hazard prelaunch is defined as a payload-related hazard, condition, or event occurring prior to launch (on ground) that could result in a mishap causing fatal injury to personnel or loss of ground facility. A catastrophic hazard post-launch is defined as a payload-related hazard, condition or event occurring post-launch (airborne) through payload separation that could result in a mishap causing fatal injury (including fatal injuries to the public) or loss of flight termination system.	Mandatory

Ref	SMA Area	Title	Requirement	Disposition
3.1.3	System Safety	Inhibits	The developer shall incorporate two (2) independent inhibits in the design (single failure tolerant) if a system failure may lead to a critical hazard. A critical hazard is defined as a condition that may cause a severe injury or occupational illness to personnel or major property damage to facilities.	Mandatory
3.1.4	System Safety	Design for Minimum Risk	The Developer shall adhere to specific detailed safety requirements, including compliance verification that must be met for design elements with hazards that cannot be controlled by failure tolerance. These design elements, e.g., structures and pressure vessels, are called "Design for Minimum Risk" areas.	Mandatory
3.2	System Safety	Launch Range Safety	The Developer shall implement launch range safety requirements as applicable for the specific launch site. The most stringent applicable safety requirement shall take precedence in the event of conflicting requirements.	Mandatory
3.2.1	System Safety	ELV Eastern Test Range (ETR) or Western Test Range (WTR) Missions Range Safety (if applicable)	a. NASA-STD 8719.24 (with Annex) NASA Expendable Launch Vehicle Payload Safety Requirements b. KNPR 8715.3, “KSC Safety Practices Procedural Requirements” (applicable at KSC property, KSC-controlled property, and offsite facility areas where KSC has operational responsibility) c. NPR 8715.7, “Expendable Launch Vehicle Payload Safety Program” d. Launch Site Facility-specific Safety Requirements, as applicable (e.g., Astrotech)	Mandatory (If applicable)
3.2.2	System Safety	ISS Safety (if applicable)	a. ISS Mission-related Safety Requirements Documentation (if applicable): b. SSP 51700 Payload Safety Policy and Requirements for the International Space c. NSTS/ISS18798 Interpretations of NSTS/ISS Payload Safety Requirements d. SSP 30599 ISS Safety Review Process	Mandatory (If applicable)
3.2.3	System Safety	KSC Missions Safety (if applicable)	KNPR 8715.3 KSC Safety Practices Procedural Requirements	Mandatory (If applicable)
3.2.4	System Safety	Dragon Missions Safety (if applicable)	a. SSP 57012 Dragon Interface Definition Document b. SSP 50835 Common Interface Requirements Document (Dragon)	Mandatory (If applicable)
3.2.5	System Safety	HTV Missions Safety (if applicable)	a. JSX-2008041B, “HTV Cargo Safety Review Process” b. JMR-002B, “Launch Vehicle Payload Safety Standard” c. JSX-2009059A, “HTV Cargo Safety Certification Process for Disposal”	Mandatory (If applicable)
3.2.6	System Safety	Japanese Missions Safety (if applicable)	a. NASA-STD 8719.24 (with Annex) NASA Expendable Launch Vehicle Payload Safety Requirements, as negotiated with JAXA and GSFC SMA Directorate b. JMR 002, “Launch Vehicle Payload Safety Requirements” c. JERG-1-007, “Safety Regulations for Launch Site Operations/Flight Control Operations” d. KDP-99105, “Safety Guide for H-II/H-IIA Payload Launch Campaign”	Mandatory (If applicable)
3.2.7	System Safety	Wallops Missions Safety (if applicable)	a. NASA-STD 8719.24 (with Annex) NASA Expendable Launch Vehicle Payload Safety Requirements b. GSFC-STD-8009, “Range Safety Manual for GSFC/WFF”	Mandatory (If applicable)

Ref	SMA Area	Title	Requirement	Disposition
3.2.8	System Safety	European Missions Safety (if applicable)	a. NASA-STD 8719.24 (with Annex) NASA Expendable Launch Vehicle Payload Safety Requirements, as negotiated by each project with ESA and b. ECSS-E-10A, "Space Engineering – System Engineering" c. ECSS-Q-40-02A, "Space Product Assurance – Hazard Analysis" d. ECSS-Q-40, "Space Product Assurance: Safety" e. CSG-RS-09A-CN, "Centre Spatial Guyanais (CSG) Safety Regulations Volumes and Parts List" f. CSG-RS-10A-CN, "Centre Spatial Guyanais (CSG) Safety Regulations Vol. I: General Rules" g. CSG-RS-21A-CN, "CSG Safety Regulations Vol. 2 Pt. 1: Specific Rules: Ground Installations" h. CSG-RS-22A-CN, "CSG Safety Regulations Vol. 2 Pt. 2: Specific Rules: Spacecraft" i. CSG-RS-33A-SE, "CSG Safety Regulations Vol. 3 Pt. 3: Substantiation and Data Sheets Concerning Payloads" j. CSG-SBU-16687, CNES, "Payload Safety Handbook" k. CNES/PN 2010 Operations of the Guiana Space Centre Facilities	Mandatory (If applicable)
3.2.9	System Safety	Russian Missions Safety (if applicable)	a. P32928-103 Requirements for International Partner Cargoes Transported on Russian Progress and Soyuz Vehicles	Mandatory (If applicable)
3.3.1	System Safety	System Safety Plan	The developer shall prepare a System Safety Program Plan (SSPP) that describes the tasks and activities of system safety management and engineering required to identify, evaluate, and eliminate or control hazards to the hardware, software, and system design by reducing the associated risk to an acceptable level throughout the system life cycle, including launch range safety requirements (DID 3-1). If desired, the SSPP can be included as a separate chapter of the MAIP.	Mandatory
3.3.2	System Safety	Safety Compliance Checklist	Safety Requirements Compliance Checklist: The developer shall document and implement a Safety Requirements Compliance Checklist to demonstrate that the payload is in compliance with NASA and range safety requirements (DID 3-2). Noncompliances to safety requirements will be documented in waivers using the NASA ELV Payload Safety Waiver Request NF1827 and submitted for approval.	Mandatory
3.3.3	System Safety	Safety Variance Requests	Project shall submit Request for Safety Variance for waivers and non-conformances to the applicable safety requirements associated only with personnel or range safety, not those associated with mission success or programmatic risks (MA-7).	Mandatory

Ref	SMA Area	Title	Requirement	Disposition
3.3.4.1	System Safety	Preliminary Hazard Analysis	The developer shall perform a Preliminary Hazard Analysis (PHA) to obtain an initial risk assessment and identify safety critical areas of a concept or system. The PHA shall be submitted as a part of the Preliminary ISAR (DID 3-4) or the Preliminary SDP (DID 3-4). It is based on the best available data, including mishap data from similar systems and other lessons learned. The developer shall evaluate hazards associated with the proposed design or function for severity, control approach (fault tolerance or design for minimum risk), and operational constraints. The developer shall identify safety provisions and alternatives that are needed to eliminate hazards or reduce their associated risk to an acceptable level. The PHA shall consider the following for identification and evaluation of hazards as a minimum: (see SMEX MAR for details) Consider incorporating descriptive language regarding the approach and what the PHA shall consider as a minimum for identification and evaluation of hazards to the DID. Otherwise, use SMEX requirement and DID 3-4 "as is."	Mandatory
3.3.4.2	System Safety	Ops and Hazards Tracking Log	Develop Operations Hazard Analysis (OHA) and Hazard Verification Tracking Log (VTL): The developer shall perform and document an Operations Hazard Analysis (OHA) and a Hazard Verification Tracking Log (VTL) to demonstrate that hardware operations, test equipment operations, and integration and test (I&T) activities comply with facility safety requirements and that hazards associated with those activities are mitigated to an acceptable level of risk (DID 3-3). The developer shall update and maintain the Hazard Verification Tracking Log during I&T activities to track open issues.	Mandatory
3.3.4.3	System Safety	Lifting Safety Requirements	The developer shall include reference to command media or a detailed process to describe formal organizational lifting practices with an overview of successful lifting history in the System Safety Program Plan (DID 3-1). The developer process is subject to NASA insight and verification for lifting and handling of sensitive flight hardware or critical ground support equipment (GSE). Developers that lack documented, successful lifting history shall follow NASA-STD-8719.9, Lifting Standard, for all lifting and handling of flight hardware or critical GSE. Project shall assess developer processes and procedures to ensure meeting the intent of NASA-STD-8719.9.	Mandatory
3.3.4.4	System Safety	Ops and Support Hazards Analysis	Operating and Support Hazard Analysis: The developer shall perform and document an Operating and Support Hazard Analysis (O&SHA) to evaluate activities for hazards introduced during testing, transportation, storage, integration, and prelaunch operations at the launch site. Its primary purpose is to evaluate the adequacy of procedures used to eliminate, control or mitigate identified hazards in order to ensure implementation of safety requirements for personnel, procedures, and equipment used during activities at the launch site. The results of the O&SHA shall be submitted as a part of the Intermediate & Final ISARs (DID 3-4) or SDP II and SDP III (DID 3-4).	Mandatory
3.3.5	System Safety	Safety Data Package (SDP)	The developer shall prepare an integrated SDP to document the results of hazard analyses identifying the prelaunch, launch and ascent hazards associated with the flight system, ground support equipment, and their interfaces in hazard reports (DID 3-4).	Mandatory

Ref	SMA Area	Title	Requirement	Disposition
3.3.6	System Safety	Safety Verfication Tracking Log	The developer shall prepare a VTL that provides documentation of a Hazard Control and Verification Tracking process as a closed-loop system to ensure that safety compliance has been satisfied in accordance to applicable launch range safety requirements. The VTL shall demonstrate the process of verifying the control of all hazards by test, analysis, inspection, similarity to previously qualified hardware, or any combination of these activities. All verifications that are listed on the hazard reports shall reference the specific test/analysis/inspection reports with a summary of the pertinent results. Results of these tests/analyses/inspections shall be available for review. The VTL shall identify hazard controls that are not verified as closed and shall be delivered to the Project Office with the final SDP III (DID 3-4). Regular updates to this log shall be provided to the Project Office electronically for review until all hazard controls are verified as closed.	Mandatory
3.3.7	System Safety	Hazardous Procedures for Payload I&T and Pre-launch Processing	The developer shall document and implement hazardous procedures that comply with applicable facility safety requirements when performing integration and test activities and pre-launch activities at the launch site (DID 3-5). The developer shall provide safety support for hazardous operations at the launch site.	Mandatory
3.3.8	System Safety	ODAR and EOMP	The developer shall provide the inputs necessary for the development of the ODAR and the EOMP deliveries per the content defined in NASA-STD 8719.14, (DID 3-6).	Mandatory
3.3.9	System Safety	Mishap Reporting and Investigation	The developer shall prepare a Pre-Mishap Plan that describes appropriate mishap and close call notification, reporting, recording, and investigation procedures (DID 3-7). The developer shall report accidents, test failures, or other mishaps and close calls promptly to NASA. The developer shall promptly investigate so as to determine the root cause. The Developer may include the Mishap Preparedness and Contingency Plan deliverable in the System Safety Program Plan (DID 3-1) in lieu of a separate deliverable as long as the preparation information contained in DID 3-7 is included.	Mandatory
4.1	Reliability	Reliability Program Plan	Reliability Program Plan: The developer shall plan, document (in MAIP) and implement a Reliability Program that interacts effectively with other project disciplines, including engineering, hardware design, software reliability, systems safety, and mission assurance. This plan shall include how the developer will be performing the analyses specified in the remainder of this section to evaluate mission risks and when additional reliability analysis techniques (e.g., RBD/prediction, FMEA (Functional, Design, or Process), PSA, and/or WCA) will be used to supplement these when needed. Reliability analysis to establish acceptable risk to mission success is recommended and may be performed per developer standard practices.	Discretionary

Ref	SMA Area	Title	Requirement	Disposition
4.2	Reliability	Reliability Analysis (Safety)	At least 90 days prior to PDR, the Developer shall complete a reliability analysis, such as fault tree analysis or failure modes and effects analysis for faults that may result in injury to personnel or the public, producing orbital debris, or threaten assets on the ground that are not owned by the Developer. Likewise, the reliability analysis shall be used to implement means to prevent faults from propagating into host platforms, such as from instrument to spacecraft or to another external host platform. The results of these analyses should be linked to hazard and other safety analyses in Section 3, in particular the inhibit requirements in section 3.2.4.	Mandatory
4.3	Reliability	Limited Life Items	Limited Life Items The developer shall document and implement a plan to identify and manage limited life items, with an emphasis on items with a shelf life, in cases of storage. Records shall be maintained for limited-life and presented at PDR, CDR, and PSR. Limited Life items are generally defined as items subject to degradation or wear-out that have a limited shelf life, operational life, or cycle life whose life expectancy is less than 2x the required life to assess the risk and /or the mitigation plans for continued use of the item. Potential limited-life items include but are not necessarily limited to: selected consumables; mechanisms; batteries; seals; thermal control surfaces; solar arrays; and, electromechanical mechanisms.	Discretionary
5.1	Software Assurance	Software Assurance Program Plan	The developer shall plan and document the software assurance program in a Software Assurance Plan (DID 5-1). The plan will address the disciplines of Software Quality, Software Safety, Software Reliability, and Software Verification and Validation (V&V) commensurate the project's risk posture. If desired, the Software Assurance Plan can be included as a separate chapter of the MAIP (DID 1-1). The developer shall identify the person responsible for directing and managing the software assurance program and interfacing with government assurance personnel.	Discretionary
5.1.1	Software Assurance	Software Quality	The developer shall evaluate software processes and work products per their documented plans and procedures, with an emphasis on configuration management, requirements management, and verification & validation. The developer shall identify, document, and communicate noncompliance issues to the project.	Discretionary

Ref	SMA Area	Title	Requirement	Disposition
5.1.2	Software Assurance	Software Safety Analysis - ID safety critical software	Developer shall identify safety critical software per NASA-STD-8719.13, Software Safety Standard. Safety-Critical Software is software that can cause, contribute to, or mitigate human safety hazards or damage to facilities. The software safety assessment and analysis is focused on hazards specific to Integration and Test, launch, and up through spacecraft separation from the launch vehicle (except for International Space Station (ISS) payloads that have constant human presence) and re-entry/recovery (where applicable). For software that is safety critical, the developer shall: a. Identify whether software can contribute to a hazard b. Identify specific software modules or functions associated with the hazard cause c. Identify hazard elimination and hazard control methodologies and associated software safety requirements d. Verify that the inhibits and controls incorporated to eliminate or mitigate hazards are effective The developer shall incorporate the results from the Software Safety Analyses, including references to the associated software requirements, into hazard reports and deliver as part of the SDP (DID 3-4).	Mandatory
5.1.3	Software Assurance	Software reliability analysis	The developer shall ensure traceability and consistency between the reliability analysis and the software design.	Discretionary
5.1.4	Software Assurance	Software Verification and Validation	The developer shall plan and implement Verification and Validation (V&V) Plans and support reviews/walkthroughs of test procedures. The developer shall witness or review results of software testing, review software discrepancy reports, and review software delivery documentation.	Discretionary
5.2	Software Assurance	Software Reviews	The developer shall plan for software peer reviews and milestone reviews to ensure that they are conducted according to documented procedures.	Discretionary
5.3	Software Assurance	Software Development Surveillance, Maintenance, and Assurance Activities	The developer shall provide access to the following: a. Schedule of software assurance reviews, audits, and assessments of the developer's processes and products b. Corrective actions from software process and product audits	Discretionary
6.1	Workmanship Program	Workmanship Program	The Developer shall implement a workmanship program to assure that electronic packaging technologies, processes, and workmanship meet mission objectives for quality and reliability. The following standards are recommended (but not required) and provided as guidance for implementing a workmanship program to assure that electronic packaging technologies, processes, and workmanship meet mission objectives:	Discretionary
6.1.1	Workmanship Program	Workmanship Program	NASA-STD-8739.1 Workmanship Standard for Staking and Conformal Coating of Print	Discretionary
6.1.2	Workmanship Program	Workmanship Program	NASA-STD-8739.4 Crimping, Interconnecting Cables, Harnesses, and Wiring	Discretionary
6.1.3	Workmanship Program	Workmanship Program	NASA-STD-8739.5 Fiber Optic Terminations, Cable Assemblies, and Installation	Discretionary
6.1.4	Workmanship Program	Workmanship Program	NASA-STD-8739.6 Implementation Requirements for NASA Workmanship Standards	Discretionary
6.1.5	Workmanship Program	Workmanship Program	GSFC-STD-6001 Ceramic Column Grid Array Design and Manufacturing Rules for Flight Hardware	Discretionary

Ref	SMA Area	Title	Requirement	Disposition
6.1.6	Workmanship Program	Workmanship Program	IPC-J-STD-001FS Joint Industry Standard, Space Applications Electronic Hardware Addendum (except Chapter 10 of IPC-J-STD-001F)	Discretionary
6.1.7	Workmanship Program	Workmanship Program	IPC-2221 Generic Standard on Printed Board Design	Discretionary
6.1.8	Workmanship Program	Workmanship Program	IPC-2222 Sectional Design Standard for Rigid Organic Printed Boards	Discretionary
6.1.9	Workmanship Program	Workmanship Program	IPC-2223 Sectional Design Standard for Flexible Printed Boards	Discretionary
6.1.10	Workmanship Program	Workmanship Program	IPC-2225 Sectional Design Standard for Organic Multichip Modules (MCM-L) and MCM-L Assemblies	Discretionary
6.1.11	Workmanship Program	Workmanship Program	IPC-A-600 Acceptability of Printed Boards (Class 3 requirements)	Discretionary
6.1.12	Workmanship Program	Workmanship Program	IPC-6011 Generic Performance Specification for Printed Boards (Class 3 requirements)	Discretionary
6.1.13	Workmanship Program	Workmanship Program	IPC-6012 Qualification and Performance Specification for Rigid Printed Boards (Class 3/A requirements). If design constraints preclude full implementation of 3/A requirements, then a waiver shall be submitted for those requirements that cannot be met due to the design constraints.	Discretionary
6.1.14	Workmanship Program	Workmanship Program	MIL-PRF-55110H Performance Specification: Printed Wiring Board, Rigid, General Specification For	Discretionary
6.1.15	Workmanship Program	Workmanship Program	IPC-6013 Qualification and Performance Specification for Flexible Printed Boards (Class 3 requirements)	Discretionary
6.1.16	Workmanship Program	Workmanship Program	MIL-PRF-50884F Performance Specification: Printed Wiring Board, Flexible or Rigid-Flex, General Specification For	Discretionary
6.1.17	Workmanship Program	Workmanship Program	IPC-6015 Qualification and Performance Specification for Organic Multichip Module (MCM-L) Mounting and Interconnecting Structures	Discretionary
6.1.18	Workmanship Program	Workmanship Program	IPC-6018 Qualification and Performance Specification for High Frequency (Microwave) Printed Boards (Class 3 requirements)	Discretionary
6.1.19	Workmanship Program	Workmanship Program	IPC- 610 Acceptability of Electronic Assemblies, or proven, comparable company practices	Discretionary
6.1.20	Workmanship Program	Workmanship Program	IPC/WHMA-A-620B, Requirements and Acceptance for Cable and Wire Harness Assemblies	Discretionary
6.2	Workmanship Program	Design and Process Qualification	Developer shall perform and document qualification of designs and processes that are not covered by or do not conform any of the above standards (if required) and submit a waiver request for government approval.	Discretionary

Ref	SMA Area	Title	Requirement	Disposition
6.3	Workmanship Program	Electrostatic Discharge Control (ESD)	The developer shall prepare and implement an ESD control program that conforms to the requirements of ANSI/ESD S20.20, Protection of Electrical and Electronic Parts, Assemblies and Equipment [Excluding Electrically Initiated Explosive Devices] (made available upon request).	Discretionary
6.4	Workmanship Program	Splices, Circuit Board Trace Cuts, and Jumper Wires	Developer shall not incorporate splices, board trace cuts, or jumper wires that result from repairs or design changes into flight hardware, including previously developed hardware, unless approved by the MRB.	Discretionary
6.5	Workmanship Program	Printed Wiring Board (PWB) Test Coupons	The developer shall provide printed wiring board test coupons to the GSFC or to a GSFC approved facility for analysis (DID 6-1). The developer shall not use printed wiring boards until coupon analysis results are approved or waived by MRB.	Discretionary
7.1	EEE Parts	Parts Control Plan	The Developer shall document and implement a Parts Control Plan (PCP)(DID 7-1). Per NASA-STD-8739.10, Level 4, or Commercial-Off-The-Shelf (COTS) parts may be used without additional screening. The Developer may include the Parts Control Plan deliverable in the Mission Assurance Implementation Plan (DID 1-1) in lieu of a separate deliverable as long as the preparation information contained in DID 7-1 is included. EEE Parts: Developer should address the following for part selection, screening and usage in the PCP when information is available: 1. Prior usage of the part and qualification for the specific application 2. Manufacturing variability with lots and from lot to lot for parts 3. Traceability and pedigree of parts 4. Reliability basis for parts. 5. Parts stress/application conditions The PCP shall address counterfeit parts in accordance with SAE AS5553.	Discretionary
7.2	EEE Parts	Nonstandard Parts	Non-standard parts are parts that do not have a military specification part number or Source Control Drawing (SCD) that reflects the required reliability level for a Level 1, Level 2, or Level 3 mission per the EEE-INST-002. Non-standard parts shall be documented, evaluated and approved by the PCB.	Discretionary
7.3	EEE Parts	Parts Control Board	The developer shall establish a process for the planning, management, and coordination of the selection, application, and procurement requirements of EEE parts. This process shall be implemented through a Parts Control Board (PCB) and shall be described in the Parts Control Plan (PCP). The Project Parts Engineer (GSFC) shall be an active/voting member of the PCB.	Discretionary
7.4	EEE Parts	Re-use of EEE Parts	The developer shall require approval of the MRB to re-use EEE parts that have been installed and removed.	Discretionary
7.5	EEE Parts	Master EEE Parts List	The Developer shall make available a list of EEE parts used in the flight hardware (DID 7-2) and include the list in the Developer's EIDP (DID 12-1).	Discretionary
7.6	EEE Parts	Parts Radiation	Effects of radiation shall be mitigated either by the use of radiation-tolerant designs that are substantiated by analyses and testing as needed or by part-by-part, board-level, or box-level radiation hardness or radiation tolerance demonstrated by analysis or testing. Information shall be included in DID 7-1.	Discretionary

Ref	SMA Area	Title	Requirement	Disposition
8.1	Materials & Process	Materials and Processes	The developer shall prepare and implement a Materials and Processes (M&P) Selection, Control, and Implementation Plan (DID 8-1). As part of the plan, the developer shall implement an M&P Control Board process or equivalent developer process, which defines the planning, management, and coordination of the selection, application, procurement, control, and standardization of M&P for the contract and for directing the disposition of M&P nonconformance and problem resolutions. NASA-STD-6016 (or equivalent developer's standard) shall form the basis for the requirements of the project's M&P Requirements. Tailoring of NASA-STD-6016 or the direct use of the developer's standard is allowed, and shall address application, launch site, and platform (e.g., ISS) specific M&P requirements. The developer shall document the tailoring in the M&P Selection, Control, and Implementation Plan to provide the degree of conformance with and the method of implementation of the requirements (NASA-STD-6016). The Project Materials and Processes Engineer (GSFC) shall be an active/voting member of the Materials and Processes Control Board or equivalent developer process.	Discretionary
8.2	Materials & Process	Materials Identification and Usage List (MIUL)	Materials Identification and Usage List (MIUL): The Developer shall prepare a Materials Identification and Usage List (DRD MA-25). No formal submittal is required. Government is to be provided access to the data. The Developer shall also provide NASA access to the Developer-generated Program Approved Parts List (PAPL) (DRD-MA-25).	Discretionary
9.1	Contamination	Contamination Control Plan	The developer shall prepare and implement a contamination control program (DID 9-1).	Mandatory
10.1	Metrology & Cal	Metrology and Calibration Program	Metrology and Calibration Program: The developer shall comply with one of the following standards for the calibration of measuring and test equipment: a. ANSI/NCSL Z540.1-1994 (R2002) Calibration Laboratories & Measuring & Test Equipment - General Requirements b. ANSI/NCSL Z540.3-2006 Requirements for the Calibration of Measuring and Test Equipment c. ISO 17025-2002 General requirements for the competence of testing and calibration laboratories	Discretionary
10.2	Metrology & Cal	Use of Non-calibrated Instruments	The Developer shall limit the use of non-calibrated instruments to applications where substantiated accuracy relative to a standard reference is not required and for indication-only purposes in nonhazardous, non-critical applications.	Discretionary
11.1	GIDEP	GIDEP Program	Government-Industry Data Exchange Program (GIDEP) The Developer may participate in GIDEP per the GIDEP Operations Manual located at http://www.gidep.org if desired. For Class D projects in institutions that are not GIDEP participants, the Developer may coordinate with NASA SMA for GIDEP content. For inherited components accepted for approval through the inherited items process or for other commercial-off-the-shelf assemblies, the requirements in this section only apply to advisories related to the component or assembly as a whole.	Discretionary

Ref	SMA Area	Title	Requirement	Disposition
11.2	GIDEP	GIDEP Alert Review	The developer shall review the following, hereafter referred to collectively as Alerts, for affects on EEE parts, materials, equipment and software used in NASA products: GIDEP Alerts; GIDEP SAFE-ALERTS; GIDEP Problem Advisories; GIDEP Agency Action Notices; NASA Advisories.	Discretionary
11.3	GIDEP	GIDEP Alert Actions	When the developer has identified an applicable item in their design, inventory, or assembly that is documented in a GIDEP or NASA advisory, the developer shall document this through their standard nonconformance reporting system as an MRB item. The developer shall eliminate or mitigate the effects of Alerts on NASA products. The disposition of the MRB will include NASA representation.	Discretionary
11.4	GIDEP	GIDEP Alert Reporting	The developer shall prepare and submit failure experience data and safety issue reports per the requirements of S0300-BT-PRO-010 and S0300-BU-GYD-010 whenever failed or nonconforming items that are available to other buyers are discovered.	Discretionary
11.5	GIDEP	GIDEP Alert Review Reporting	The developer shall report the status of NASA products that are affected by Alerts or by significant EEE parts, materials, and safety problems at monthly status reviews, parts control board meetings, program milestone reviews and readiness reviews. The developer shall include a summary of the review status for EEE parts and materials lists and of actions taken to eliminate or mitigate negative effects.	Discretionary
12.1	Ground Equipment	Ground Protection of Flight Hardware	The Developer shall evaluate the potential for GSE to damage flight hardware by electrical or mechanical means, use appropriate means to prevent such damage from occurring, and present the approach at PDR and CDR.	Mandatory
13.1	Digital Electronics	Digital Electronics	Digital Electronics Assurance Plan The Developer shall document and implement an assurance plan for digital electronic components and designs that do not have flight heritage in a comparable space environment (DRD MA-28). EEE parts aspects of digital electronic parts are addressed in Section 8. Covered digital electronic components are: a. Gate array technologies, including mask programmed gate arrays, field programmable gate arrays, custom ASICs, and the digital sections of mixed-signal ASICs b. And-Or plane devices, such as PALs and PLAs The plan does not apply to software or firmware executed on processors or memory devices. The developer shall identify the person responsible for directing and managing the digital electronic components assurance program and interfacing with government assurance personnel.	Discretionary

Ref	SMA Area	Title	Requirement	Disposition
14.1	Planet Protect	Planetary Protection	Planetary Protection For missions outside of Earth orbit, the Developer shall take measures to address forward contamination (transmittal from Earth to a targeted Solar System body) and backward contamination (transmittal to Earth from the targeted body) with respect to other Solar System bodies. The following documents apply: a. NPD 8020.7G, Biological Contamination Control for Outbound and Inbound Planetary Spacecraft b. NID 8020.109, Planetary Protection Provisions for Robotic Extraterrestrial Missions c. NASA-HDBK-6022, NASA Handbook for the Microbiological Examination of Space Hardware Note that forward contamination is of particular concern for Mars, Europa, Enceladus, and for possible liquid water bodies within other icy satellites.	Discretionary
15.1	Cybersecurity	Cybersecurity and Command Link Protection	The Developer shall take measures to protect the integrity of on-board and ground control data systems based on risks present. Spacecraft capable of maneuvering shall incorporate command link protection compliant with FIPS 140-2. All command information shall be protected as SBU. Document implementation approach in the System Security Plan in conjunction with the project protection plan.	Mandatory
16.1	End Item Accept	End Item Acceptance Data Package	The developer shall submit an end item acceptance data package (DID 12-1).	Mandatory
DID 1-1	General	MAIP	Develop MAIP (DID-1)	Mandatory
DID 2-1	Quality Mgmt	Review MRB Actions as requested by the Project Team	Review MRB Actions as requested by the Project Team	Mandatory
DID 2-2	Quality Mgmt	Review Anomaly Reports as requested by the Project Team	Review Anomaly Reports as requested by the Project Team	Mandatory
DID 3-1	System Safety	System Safety Program Plan	System Safety Program Plan	Mandatory
DID 3-2	System Safety	Safety Requirements Compliance Checklist	Safety Requirements Compliance Checklist	Mandatory
DID 3-2a	System Safety	Request for a Safety Variance	Request for a Safety Variance	Mandatory
DID 3-3	System Safety	Operations Hazard Analysis and Hazard Verification Tracking Log	Operations Hazard Analysis and Hazard Verification Tracking Log	Mandatory
DID 3-4	System Safety	Instrument Safety Assessment Report or Safety Data Package	Instrument Safety Assessment Report or Safety Data Package	Mandatory
DID 3-5	System Safety	Hazardous Procedures for Payload I&T and Pre-Launch Processing	Hazardous Procedures for Payload I&T and Pre-Launch Processing	Mandatory
DID 3-6	System Safety	Orbital Debris Assessment Report (ODAR) and End of Mission Plan (EOMP)	Orbital Debris Assessment Report (ODAR) and End of Mission Plan (EOMP)	Mandatory

Ref	SMA Area	Title	Requirement	Disposition
DID 3-7	System Safety	Mishap Preparedness and Contingency Plan or Pre-Mishap Plan	Mishap Preparedness and Contingency Plan or Pre-Mishap Plan	Mandatory
DID 4-1	Reliability	Fault Tree Analysis	Fault Tree Analysis	Discretionary
DID 5-1	SW Assurance	Software Assurance Plan	Software Assurance Plan	Discretionary
DID 6-1	Workmanship	Printed Wiring Board Test Coupons	Printed Wiring Board Test Coupons	Discretionary
DID 7-1	EEE Parts	EEE Parts Control Plan (PCP)	EEE Parts Control Plan (PCP)	Discretionary
DID 7-2	EEE Parts	Master EEE Parts List	Master EEE Parts List	Discretionary
DID 8-1	Materials & Process	Materials & Processes Selection, Control, and Implementation Plan	Materials & Processes Selection, Control, and Implementation Plan	Discretionary
DID 8-2	Materials & Process	Materials Identification and Usage List	Materials Identification and Usage List	Discretionary
DID 9-1	Contamination	Contamination Control Plan and Data	Contamination Control Plan and Data	Mandatory
DID 12-1	End Item Accept	End Item Acceptance Data Package	End Item Acceptance Data Package	Mandatory

AEROSPACE REPORT NO.
ATR-2023-01224

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AEROSPACE REPORT NO.
ATR-2023-01224

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