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Promoting a Culture of Tailoring for Systems Engineering Policy Expectations

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Abstract

NASA's Marshall Space Flight Center (MSFC) has developed an integrated systems engineering approach to promote a culture of tailoring for program and project policy requirements. MSFC's culture encourages and supports tailoring, with an emphasis on risk-based decision making, for enhanced affordability and efficiency. MSFC's policy structure integrates the various Agency requirements into a single, streamlined implementation approach which serves as a "one-stop-shop" for our programs and projects to follow. The engineers gain an enhanced understanding of policy and technical expectations, as well as lesson's learned from MSFC's history of spaceflight and science missions, to enable them to make appropriate, risk-based tailoring recommendations. The tailoring approach utilizes a standard methodology to classify projects into predefined levels using selected mission and programmatic scaling factors related to risk tolerance. Policy requirements are then selectively applied and tailored, with appropriate rationale, and approved by the governing authorities, to support risk-informed decisions to achieve the desired cost and schedule efficiencies. The policy is further augmented by implementation tools and lifecycle planning aids which help promote and support the cultural shift toward more tailoring. The MSFC Customization Tool is an integrated spreadsheet that ties together everything that projects need to understand, navigate, and tailor the policy. It helps them classify their project, understand the intent of the requirements, determine their tailoring approach, and document the necessary governance approvals. It also helps them plan for and conduct technical reviews throughout the lifecycle. Policy tailoring is thus established as a normal part of project execution, with the tools provided to facilitate and enable the tailoring process. MSFC's approach to changing the culture emphasizes risk-based tailoring of policy to achieve increased flexibility, efficiency, and effectiveness in project execution, while maintaining appropriate rigor to ensure mission success.

Keywords: project management; systems engineering; integrated, flexibility; tailor; requirements; cost; schedule; effectiveness, programs, projects, lifecycle

1. Introduction

NASA MSFC has a long history of successful mission execution, and systems engineering excellence, in the areas of propulsion, space transportation and launch vehicles, space systems, and scientific research. MSFC has established a wealth of policy requirements and associated technical rigor in a variety of policy documents, in order

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to ensure mission success and minimize risk of failure. MSFC has recently adopted a more integrated approach to tailor policy expectations, with an emphasis on risk-based decision making for enhanced affordability and efficiency.

2. Background

NASA's program/project policy recognizes a generic program and project management lifecycle concept with variations for each of the Agency's primary mission areas. The variation is primarily in terms of the number of technical reviews and associated products that are expected for each lifecycle type. NASA lays out the basic systems engineering processes and the technical review expectations, and requires each Center to further define its systems engineering processes, technical reviews and product requirements, based on that Center's unique portfolio of projects, and the type of missions that they execute. The majority of MSFC's projects produce aerospace end products which support one of the following three primary mission areas: spaceflight systems for human or robotic exploration and operations in space, space technology development, and scientific research.

Over the years, NASA's policy approach had resulted in a complex array of different lifecycle types, depending on the particular mission area supported, each one having different expectations for the number and type of programmatic and technical reviews to be executed, and the associated project planning and technical data products expected to be delivered at various states of maturity for each review. The result was a complex set of policy requirements and expectations, which required each program and project to invest a significant amount of time and effort to navigate, understand, and integrate the various expectations to determine which requirements were applicable and which provided value for the particular project case. This approach was not the most efficient for the smaller projects and activities, which represented an increasing percentage of MSFC's business portfolio. Promoting affordability, efficiency, and risk-informed decision making, MSFC has implemented an approach that consisted of the following steps: integrating and streamlining policy expectations to enhance understanding, establishing a consistent methodology to scale policy expectations based on acceptable risk levels, and implementing tools to promote tailoring.

3. Integrate and Streamline Policy Expectations

MSFC uses an integrated approach to flow down NASA's top-level Program/project expectations into Center policy[1]. All of the Agency's requirements are integrated into our top level document, MPR 7120.1, *MSFC Engineering and Program/Project Management Requirements*[2], which addresses all of MSFC's primary mission areas (spaceflight, technology development, and scientific research). It serves as a "one-stop-shop" by providing an integrated policy document that our programs and projects can go to for a single source to understand everything that is required to meet stakeholder expectations for project execution, and incorporating over 50 years of lessons learned. It provides an integrated set of policy requirements for each lifecycle type, including the applicable reviews and product maturity expectations for each type. It also establishes requirements to ensure a minimum level of rigor in technical execution, based on lesson's learned from MSFC's prior project experience, and specific direction from MSFC's governing authority. Each program and project is expected to assess a standard suite of systems engineering processes and life-cycle reviews for applicability to their particular project case[3]. Figure 1 illustrates MSFC's policy flow down approach.

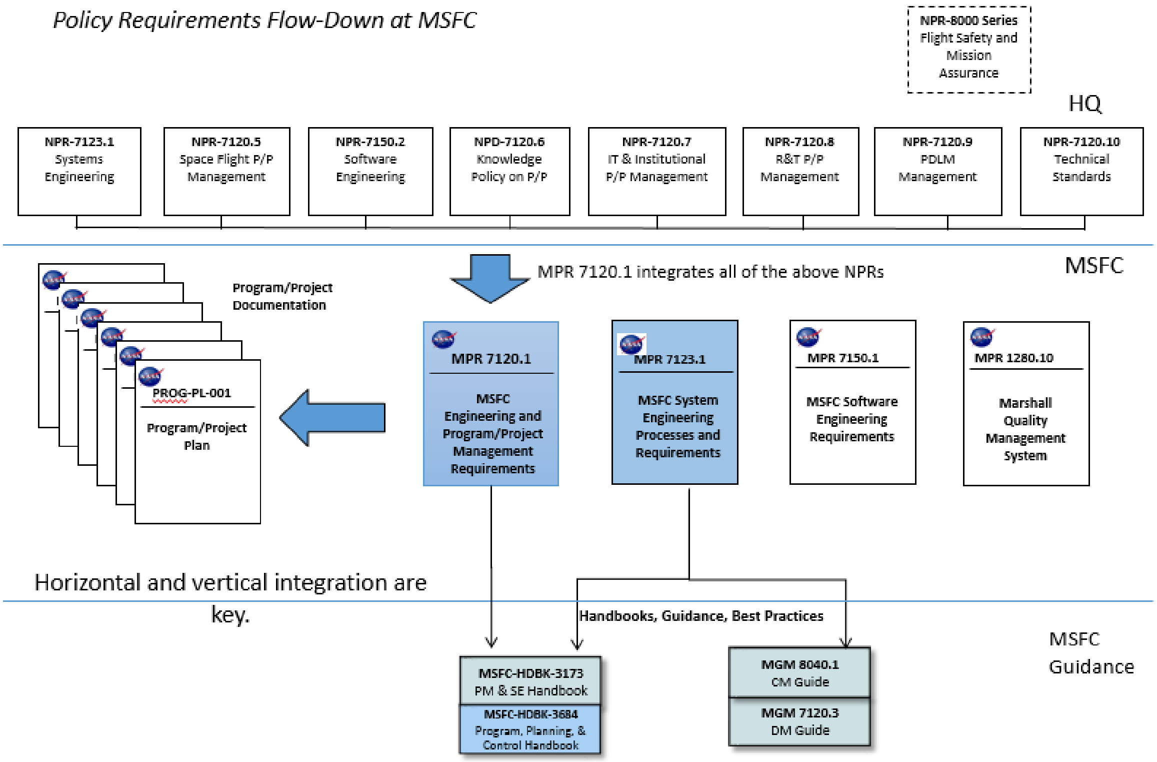

Figure 1 – MSFC Policy Flow Down

4. Change the Culture from an Emphasis on Policy Compliance to Policy Tailoring

MSFC program/project policy had grown in accordance with our successes and failures over the many years of space flight and science missions. As a result the management and engineering cultures had gradually changed into a somewhat risk averse approach to implementation, versus a more efficient, risk-informed approach. Tailoring was practiced in unusual circumstances. In order to enable a more flexible, risk-based approach to implementation, the policy suite is designed to encourage management and engineering personnel to assess the intent of requirements, guidance, and best practices, for applicability given the risk posture of their particular project. Projects may adapt their implementation to best fit their needs, or tailor those requirements for which the intent is not applicable, to better align with what is needed for mission success. This allows for a more discerning and creative culture, as engineers are equipped with a better understanding of the lessons from NASA’s heritage and the ‘why’ behind program/project policy as they think through an appropriate, risk-based, implementation approach. The MSFC policy suite promotes a culture that utilizes risk-informed decision making to enable appropriate tailoring, by taking into account each project’s particular mission and programmatic characteristics, as well as the intended application of the policy requirements.

The projects are required to perform a compliance assessment to determine their approach for implementing the requirements and any additional tailoring that may be needed for their particular project case. The results are presented for the approval of MSFC’s governing authorities through our established governance councils. The compliance assessment and tailoring approval process is designed to facilitate tailoring, and the associated record keeping, by providing one single integrated compliance matrix which can serve as the record to document all of the projects compliance and tailoring requests. By establishing and facilitating the compliance assessment and governance approval process, the policy builds a culture that is more focused on risk-based tailoring considerations as a normal part of project formulation.

5. Establish a Consistent Methodology to Scale Policy Expectations for Project Implementation

NASA MSFC's approach utilizes a standard set of scaling factors to classify projects into eight pre-defined levels called mission types. The scaling factors include the 1) mission criticality and significance within NASA's overall strategic plan, 2) acceptable tolerance for the risk of not achieving mission success, 3) system complexity, 4) expected magnitude of the Agency's investment cost, 6) expected mission lifetime, and 6) primary mission areas supported. These factors were chosen to provide management and engineering personnel with a common, consistent language to help guide and inform risk-based decision making when tailoring policy requirements.

This project classification scheme is used in several ways at MSFC. First, the mission types are used to define the intended applicability of selected technical and programmatic products. The mission type levels are also used as the basis for recommending, customized implementation approaches for specific products and technical reviews. These customized implementation approaches were developed based on lesson's learned from past projects, and include recommendations and best practices for implementing various products with varying degrees of rigor and complexity. These customized approaches are intended to serve as a starting point for each project to consider, as they plan their own specific project implementation approach. This encourages projects to begin considering alternate ways to implement the requirement, and thus it stimulates a culture of innovative thinking that is focused on each project's particular needs. The mission types also provide the common framework within which the projects assess the policy requirements, and decide how much further tailoring to request, based on their own particular risk and mission characteristics, as compared against the standard mission type categories. The MSFC governing authorities also utilize this common mission type framework, as the backdrop against which they make risk-informed decisions when reviewing and approving specific project tailoring requests. Figure 2 shows MSFC's project and activity categorization into the mission type levels.

Through the use of the mission type classification scheme, MSFC's approach encourages tailoring the policy expectations to align with the size, scope, and risk tolerance of the project, and the nature of the mission to be accomplished. This promotes a culture in which the focus of the discussions is on accepting appropriate risk to achieve cost and schedule efficiencies, while maintaining the appropriate rigor to ensure that critical mission objectives are accomplished.

Project and Activity Categorization/Mission Types								
	Projects						Activities	
	Type 1	Type 2		Type 3			Type 4	Type 5
		2.a	2.b	3.a	3.b	3.c		
Cost Guidance (Estimated LCC)	greater than $1B	$1B - $250M	$250M - $100M	$100M - $50M	$50M - $10M	less than $10M	typically [1] greater than $1M/yr or greater than $10M LCC	typically [1] less than $1M/yr or less than $10M LCC
Priority (Criticality to Agency Strategic Plan)	Any	Any	High	Medium or low priority	Low priority	Low to very low priority	High to Agency or Center	Medium or Low
Other Factors	Significant Radioative Material							
Decision Authority	NASA Associate Administrator	NASA Mission Directorate Associate Administrator		NASA Mission Directorate Associate Administrator or Designee			Center Director or Designee	Directorate/Office Manager or Designee
Governing PMC	Agency	Mission Directorate		Mission Directorate			CMC	Monthly Program Reviews Within Directorate/Office
National Significance	Very high	High	Medium	Medium	Low	Very Low		
Risk Tolerance	Class A Risk: Very low (minimized)	Class B Risk: Low	Class C Risk: Medium	Class D Risk: High	Class D Risk: High	Class D Risk: High		
Description of the Types of Mission	Human Space Flight or very large Science/Robotic Missions	Non-Human Space Flight or Science/Robotic Missions	Small Science (Human or Non human)	Smaller Science (Human or Non human)	Science (Human or non human)	Science (Human or non human)	Efforts supporting program/projects managed outside of MSFC, that come under the purview of the CMC per the criteria defined in MPR 7120.4	Efforts supporting program/project managed outside of MSFC, that do not come under the purview of the CMC per the criteria defined in MPR 7120.4
Complexity	Very high to high	High to Medium	Medium to Low	Low	Low	Low to Very Low		
Mission Lifetime (Primary Baseline Mission)	Long (>5 years)	Medium (2-5 years)	Short (<2 years)	Short (<2 years)	Short (<2 years)	Short (<2 years)		
Launch Constraints	Critical	Medium	Few to none	Few to none	Few to none	None		
Achievement of Mission Success Criteria	All practical measures are taken to achieve minimum risk to mission success. The highest assurance	Stringent assurance standards with only minor compromises in application to maintain a low risk to mission success.	Medium or significant risk of not achieving mission success is permitted. Minimal assurance standards are	Significant risk of not achieving mission success is permitted. Minimal assurance standards are permitted.	Significant risk of not achieving mission success is permitted. Minimal assurance standards are	Significant risk of not achieving mission success is permitted. Minimal assurance standards are permitted.		
Examples	HST, Chandra, Cassini, JIMO, JWST, MPCV, SLS, ISS	MER, MRO, Discovery payloads, ISS Facility Class payloads, Attached ISS payloads	ESSP, Explorer payloads, MIDES, ISS complex sub rack payloads, PA-1, ARES 1-X, MEDLI,	SPARTAN, GAS Can, technology demonstrators, simple ISS, express middeck and sub rack payloads, SMEX, MISSE-X, EV-2	IRVE-2, IRVE-3, HiFIRE, HyBoLT, ALHAT Earth Venture I, FASTSAT	DAWNAir, InFlame, Research, technology demonstrations, HEROES, SWORDS Payloads, Nanosails	ADDITIVE Manufacturing in Space	MSFC activities in support of a request from program/project outside of MSFC, for MSFC supporting activities. Subject to requesting organization's requirements.

Figure 2 – Project and Activity Categorization Table

6. Implement Appropriate Tools to Enhance Understanding and Promote Tailoring of the Policy

The MSFC Customization Tool is an integrated, automated spreadsheet that is used to help projects understand and manage the applicable requirements, products, and lifecycle review expectations, based on the project's lifecycle and mission type characteristics. The tool contains all the requirements, guidance, product maturity specifications, and lifecycle review expectations that are applicable for all lifecycle and mission types. The tool includes the standard project classification schema to help engineers determine the most appropriate "best fit" classification level for their particular project. First, the tool automatically filters the information to present a customized view for each project, showing only that information which is applicable to that particular project, based on the selected project lifecycle and mission type characteristics. In this way, the tool promotes greater efficiency by allowing the projects to focus their tailoring efforts on just those requirements that are intended to be applicable for their type. This benefits the cultural change because it helps the projects better understand the intended application of the requirements, and helps them concentrate their efforts on those requirements that are pertinent for their selected lifecycle/mission type. It allows the limited resources of small projects to be better utilized by limiting the conversation to just those requirements necessary for them, and prevents them from spending time and effort on those that don't apply.

The tool provides some recommended, customized implementation approaches for selected requirements and products. The recommended approaches are offered to provide some possible ideas for alternate ways to address the requirement, but also is intended to stimulate the engineers to think of additional implementation approaches on their own. The tool allows the engineer to assess the recommended approach for each requirement and choose to implement as recommended, or to modify the recommended approach, or to reject the recommendation and replace it with their own implementation approach, or to determine that the requirement is not applicable for their particular project based on its unique characteristics. The engineer is thus encouraged to think beyond just merely complying with the requirement, to also begin to consider alternative ways to implement it. This benefits cultural change by encouraging the engineers to consider why the requirement was originally established, and to explore innovative ways to accomplish the intent.

Figure 3 shows an example of a small MSFC project that used the tool to consider recommended customization and determine their actual customization approach. This example is from "3D Printing in Zero-G" which was a small technology demonstration project that flew onboard the International Space Station in the Microgravity Science Glovebox (MSG). It demonstrated additive manufacturing technology in a microgravity environment. This project was a Mission Type 4 activity. It had relatively low cost, but high visibility for the Agency and MSFC due to the nature of technology being demonstrated, and relatively high acceptable tolerance to risk). Note that the project's actual approach differed from recommended implementation on several items, due to project specific factors noted in comments column. The tool helps to promote and facilitate those project unique determinations.

		Type 3.c	Type 4		Actual Customization			
Life Cycle Type	**Products** Black text = Agency required, Red text = Agency guidance Green text = MSFC (added) required, Blue text = MSFC (added) guidance	**Manned Flight**	**Manned Flight**	**Additional guidelines/commments**	**Implemented as recommended**	**Modified**	**N/A**	**Comments**
TD Project	11. Verification and Validation Report	Project Plan Appendix	Activity Plan Appendix	Required. Document in form suitable for technical review.	x			**Final report after all V&V activities and before FU delivery**
TD Project	12. Operations Handbook, if applicable			Required	x			**Flight operations prepared by MSG for ISS crew**
TD Project	13. Orbital Debris Assessment per NPR 8715.6 [5]	NA	NA	Required for LEO. Document in form suitable for technical review.			x	**Mission operates inside ISS**
TD Project	14. End of Mission Plans per NPR 8715.6/NASA-STD	Project Plan	Activity Plan	Required. May be combined with other plans.		x		**The Printer will be brought back and retained by NASA**
TD Project	15. Mission Report (Final Report from Closeout Review)			Required	x			**Fiinal report will be completed at end of mission**
TD Project	2. TD Project Plan		Activity Plan	Required		x		**The Activity Plan will be called a Project Plan and tailored for a Type 4**
TD Project	Systems Engineering Applicability Assessment (EMC approved)			Required	x			**Systems Engineering matrix to show compliance is complete**
TD Project	Technical Review Applicability Assessment (CMC approved)			Required		x		**Per approval of CMC, each review will have individual Review Plan**
TD Project	Plans for work to be accomplished during next Implementation life cycle phase	Included in Review Data	Included in Review Data	Required. May be documented in the form of review presentation material.		x		**Action list will be kept to follow forward actions to complete work**
TD Project	Documentation of performance against plans for work to be accomplished during next implementation phase, including performance against baselines and status/closure of formal actions from previous KDP	Included in Review Data	Included in Review Data	Required. May be documented in the form of review presentation material.		x		**RFA's will be closed out at each new review (KDP) and actions for next phase kept on an Action item list**
TD Project	1. Technical, Schedule, and Cost Control Plan	Project Plan	Activity Plan	Required. May be combined with other plans.	x			**Project Plan, Sections 2.4 and 3.1**
TD Project	4. Acquisition Plan	Project Plan	Activity Plan	Required. May be combined with other plans.		x		**Contract to MIS**
TD Project	6. Systems Engineering Management Plan (may be combined with TD Project Plan)	Project Plan	Activity Plan	Required. May be combined with other plans.	x			**Project Plan, Section 3.6**

Instructions | Overview (R&T) | **Customization (R&T)** | LC Reviews with Custom (R&T) | LC Reviews Guidance (R&T) | LC REVIEW EES_Criteria (R&T)

Figure 3 – Example of Customization Approach

The tool also provides the engineers with an integrated compliance matrix that they use to assess and document their project's compliance with, or their intent to tailor with rationale, for each of the policy requirements. The tool also helps them understand the governing authority approvals that are needed for tailoring each specific requirement. The tool provides an integrated, consistent methodology to document all the tailoring requests, associated rationale/justification, and the approvals of the appropriate governing authorities in a single location. The intent is to promote the culture of tailoring, by streamlining and facilitating the tailoring process, and reducing the burden on the policy implementers, as much as possible, in order to encourage and promote the appropriate discussions between the implementers and governing authorities to drive out the right amount of technical rigor and technical review for each project case. By reducing the burden on projects, the result is that more time and resources are available to assess and tailor the policy, based on the project's needs, for increased efficiency and affordability.

Figure 4 shows an example of a small MSFC project that used the tool to document their compliance assessment. This example is from the Marshall Grazing Incidence X-ray Spectrometer (MaGIXS) project which is a very small research investigation activity that was awarded to MSFC under the NASA Research Announcement (NRA) for Research Opportunities in Space and Earth Sciences (ROSES) to study solar coronal heating by measuring the solar spectrum. This instrument will fly a suborbital mission onboard a Sounding Rocket, and as a Mission Type 5 activity it represents one extreme of the mission type scale (i.e. very low cost, low criticality, high acceptable tolerance to risk). Note that the project determined that several items were not applicable, based on mission type level, but was fully compliant with the majority of the requirements, which were already streamlined to a great extent for this low level mission type 5 activity.

NPR # and Section	MPR 7120.1 Section	MPR 7120.1 Requirement Statement	Approvals Required for Tailoring	Program/Project Compliance			Approval Signatures for Tailoring
				Program/ Project Documentation	Comply? (Full, Tailored, or NA)	Rationale for Decisions, Comments, Waiver/Deviations	
MSFC Derived	28.3	Type 4 and 5 activities shall report the results of the Activity Agreement and Activity Plan to the Director of the MSFC office responsible for managing the activity and to the Engineering Director. The Directors may choose to impose additional project management requirements as determined appropriate based on the particular characteristics of that activity.	CD	MaGIXS Activity Plan, MPR 7120.1 Compliance Matrix Appendix	Full		
MSFC Derived	28.4	Type 4 activities shall also report the results of the Activity Agreement and Activity Plan to the Associate Director, Technical and the Center Director, who may choose to impose additional project management requirements as determined appropriate based on the particular characteristics of that activity.	CD	MaGIXS Activity Plan	N/A	MAGIXS is categorized as a Mission Type 5 Activity per guidance provided in MPR 7120.1, Table 3-1.	
MSFC Derived	28.5	Type 4 and 5 activities shall determine applicability of the following recommended technical reviews, as described in MPR 7123.1. The recommended technical reviews are SRR, PDR, CDR, Design Certification Review (DCR)/ System Acceptance Review (SAR) or Pre-Ship Review, and FRR. Category 4 and 5 activities may customize the entrance/exit/success criteria and degree of formality of the reviews, or combine reviews; provided that they include the minimum data content necessary to accomplish the objectives of each review and satisfy the success criteria that is applicable for that particular activity, as indicated in MPR 7123.1.	CD	MaGIXS Activity Plan	Full		
MSFC Derived	28.6	Type 4 and 5 activities shall assess the seventeen systems engineering processes, as described in MPR 7123.1, to determine applicability of each process for their particular activity, and complete the MPR 7123.1 compliance matrix for those that are determined applicable.	CD	MaGIXS Activity Plan, MPR 7123.1 Compliance Matrix Appendix	Full		
MSFC Derived	28.7	Type 4 and 5 activities shall report the results of the Technical Review and Systems Engineering Applicability Assessments to the Director, Engineering Directorate, for approval and follow the requirements in MPR 7123.1 for those processes determined applicable by the Engineering Director. The Engineering Director may choose to impose additional systems engineering requirements as determined appropriate based on the particular characteristics of that activity.	CD	MaGIXS Activity Plan, MPR 7123.1 Compliance Matrix Appendix	Full	Presentation to the Director, Engineering Directorate (EMC) on the System Engineering Applicability Assessment MPR 7123.1 compliance assessment. Request delegation to the STO Manager and STO Chief Engineer.	
MSFC Derived	28.8	Type 4 activities shall also report the results of the Technical Review and Systems Engineering Applicability Assessments to the Associate Director, Technical and the Center Director, who may choose to impose additional systems engineering requirements as determined appropriate based on the particular characteristics of that activity.	CD	MaGIXS Activity Plan	N/A	MAGIXS is categorized as a Mission Type 5 Activity per guidance provided in MPR 7120.1, Table 3-1.	

Figure 4 – Example of Compliance Assessment

The tool also provides matrices that summarize all of the required products, entrance and success criteria, and best practices, recommended products and the associated maturity levels for each of the technical and programmatic reviews within the project's applicable lifecycle. This information is provided to further aid the project implementers to help them tailor their review planning expectations to match the unique needs and characteristics of their project and mission objectives.

The MSFC Customization Tool is intended to promote and facilitate the process of tailoring policy. It is derived from the Agency's compliance matrix concept, but includes additional features to further facilitate and simplify the process for MSFC projects. The tool is currently implemented in Microsoft Excel with a Visual Basic for Applications software component, but has the potential to evolve to a more powerful platform, in order to take advantage of potential benefits of modeling policy within an integrated model-based systems engineering environment. In a model-based environment, the policy could be captured in a model that contains not only the policy requirements, but also the associated metadata that defines the applicability and recommended implementation approaches based on project scale, complexity, and risk factors.

7. Conclusions

MSFC's systems engineering policy is designed to provide an integrated, streamlined set of expectations for our programs and projects to simplify the task of the policy implementers. The goal is to help the policy implementers better understand the intent and applicability of the established policy, so that they can focus their efforts on assessing the policy intent against their own particular project characteristics, to enable them to bring forward appropriate justifications for risk-based tailoring decisions. The MSFC Customization Tool is intended to promote and facilitate the process of tailoring policy expectations based on engineering rigor necessary to meet the risk posture of a given program or project. The MSFC tool is derived from the Agency's compliance matrix concept, but includes additional features to further facilitate and simplify the process for MSFC projects. The tool is focused on MSFC's particular policy implementation of the more general, top level Agency requirements, and includes recommended, customized implementation approaches. As each project develops their own tailoring approach, and brings it forward for approval at the Center level, the MSFC governance authorities are provided with the necessary visibility and oversight to allow them to make risk-informed decisions to authorize tailoring to enhance affordability and promote schedule efficiencies, while still maintaining appropriate rigor to ensure mission success. Future implementation of program/project policy within an integrated, model-based environment will significantly empower a thinking, agile, risk-based culture, by enabling projects and governing authorities to utilize the capabilities of modelling, and the associated metadata, as they assess and tailor policy expectations. This will further strengthen and solidify the culture of tailoring policy expectations, based on agreed to risk postures for mission success, efficiency, and affordability.

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References

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3. Marshall Space Flight Center, Chief Engineers Office, MPR 7123.1, "*MSFC Systems Engineering Processes and Requirements*", revision C, May 18, 2015.