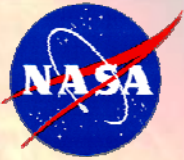


Mitigating the Adverse Impact of Technology Maturity

Project Management Challenge 2007
Fourth Annual NASA Project Management Conference

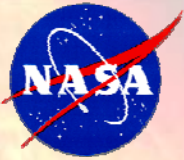
February 6-7, 2007

James W. Bilbro
Assistant Director for Technology/Chief Technologist
George C. Marshall Space Flight Center



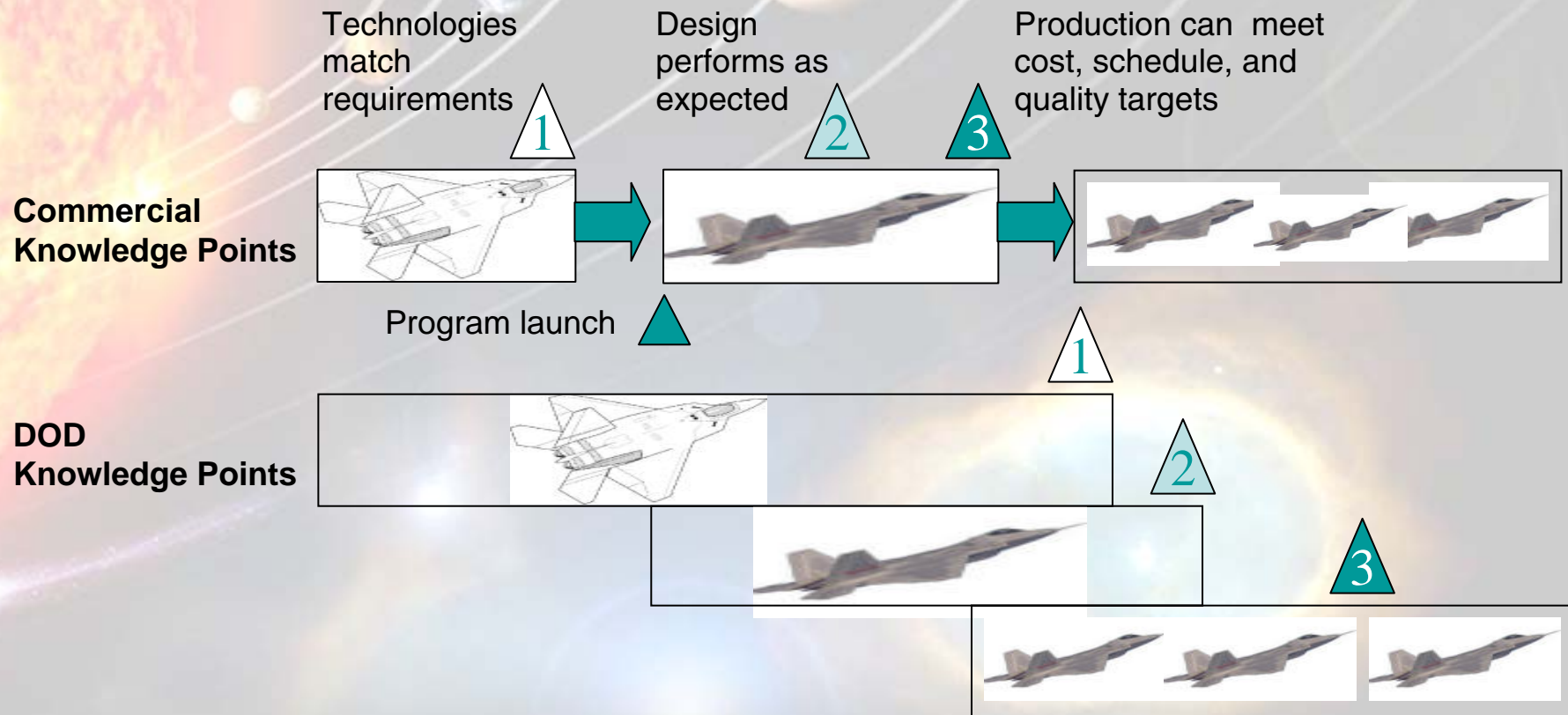
Mitigating the Adverse Impact of Technology Maturity

- **Why do Technology Assessment?**

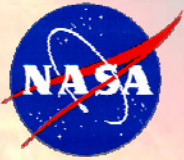


Mitigating the Adverse Impact of Technology Maturity

Knowledge Building for Development of New Products*

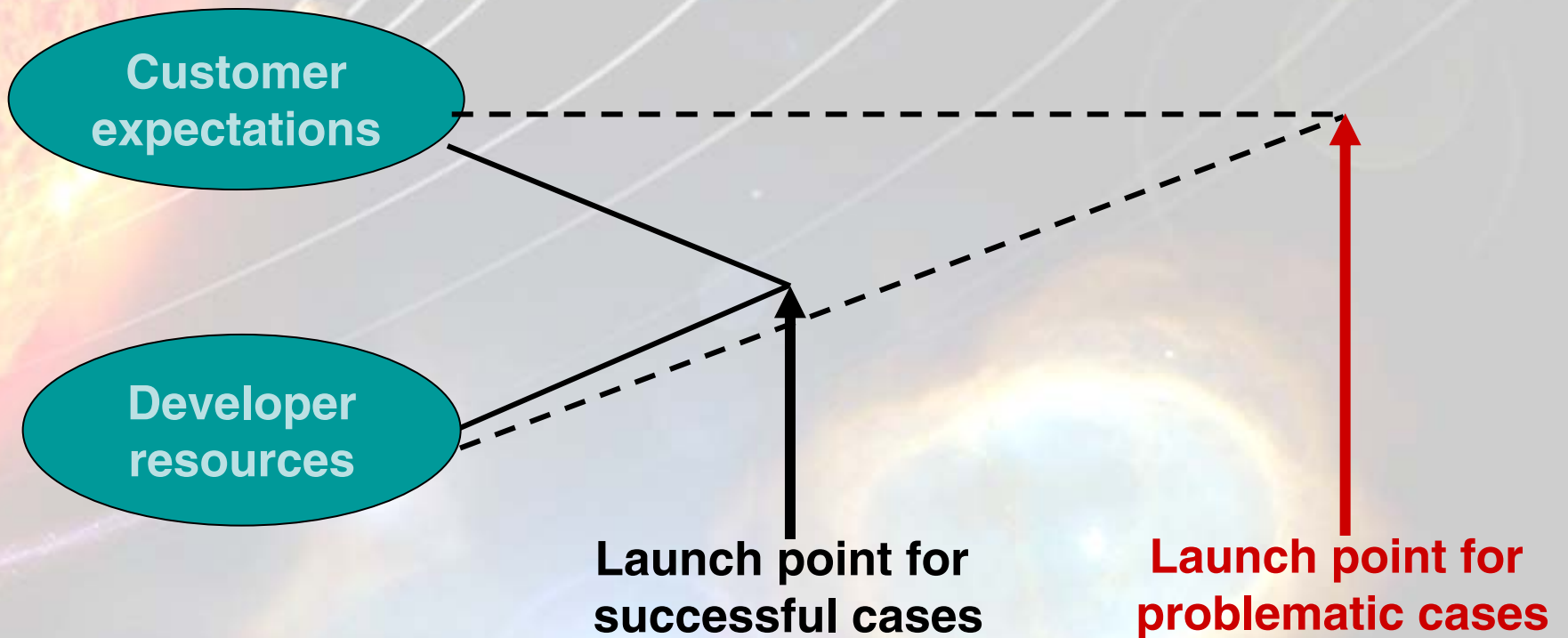


*GAO

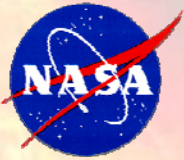


Mitigating the Adverse Impact of Technology Maturity

Timing of Match Between Customer Expectations and Developer Resources*

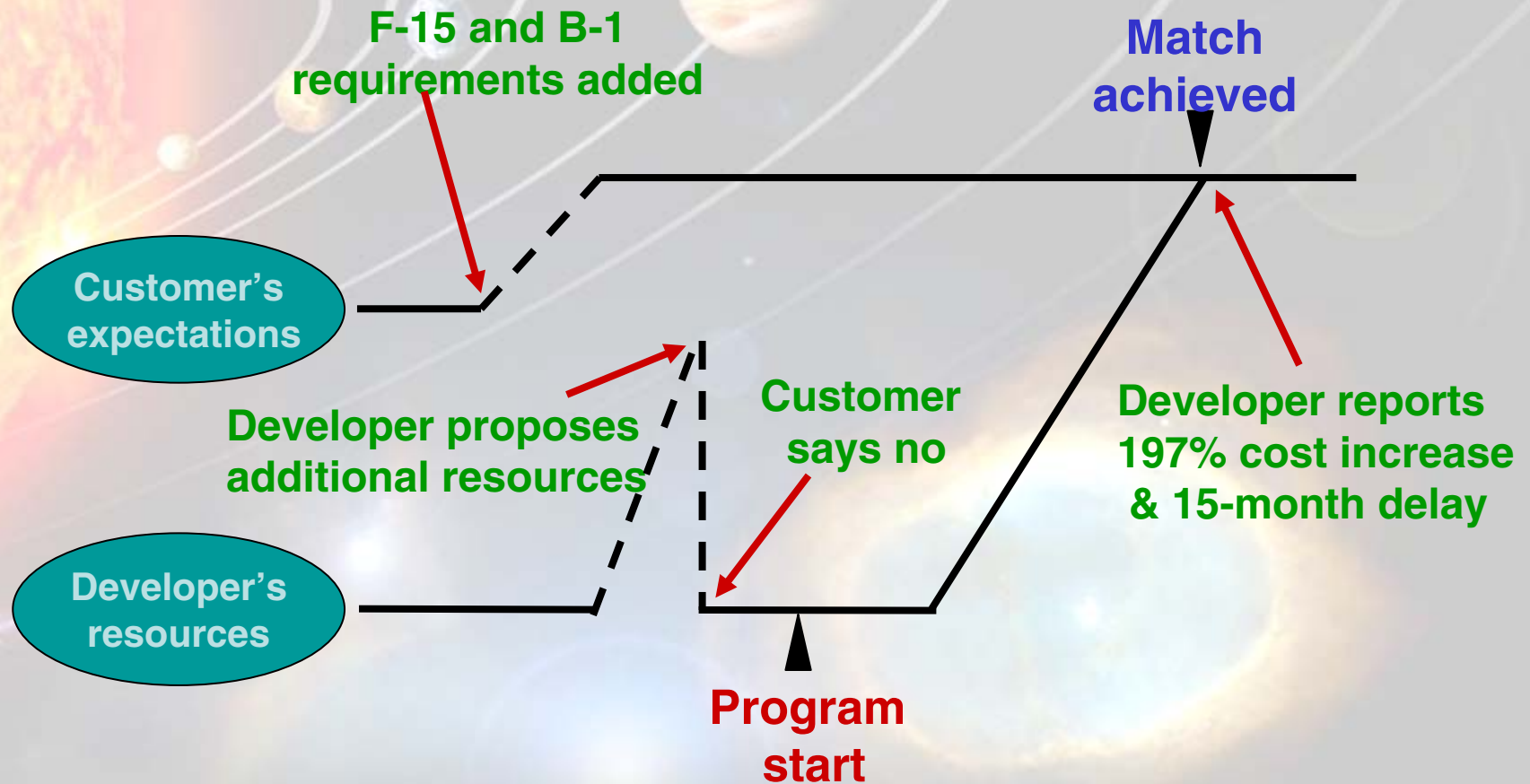


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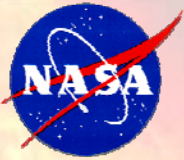


Mitigating the Adverse Impact of Technology Maturity

Development of the Radio Frequency Countermeasures System*



*GAO



Mitigating the Adverse Impact of Technology Maturity

NPR 7120.5d Requirements

KDP A – Transition from Pre-Phase A to Phase A:

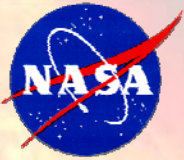
Requires an assessment of potential technology needs versus current and planned technology readiness levels, as well as potential opportunities to use commercial, academic, and other government agency sources of technology. Included as part of the draft integrated baseline.

KDP B – Transition from Phase A to Phase B:

Requires a Technology Development plan identifying technologies to be developed, heritage systems to be modified, alternate paths to be pursued, fall back positions and corresponding performance de-scopes, milestones, metrics and key decision points. Incorporated in the preliminary Project Plan.

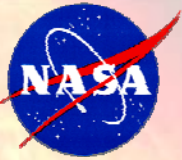
KDP C – Transition from Phase B to Phase C/D:

Technology Readiness Assessment Report (TRAR) demonstrating that all systems, subsystems and components have achieved a level of technological maturity with demonstrated evidence of qualification in a relevant environment.



Mitigating the Adverse Impact of Technology Maturity

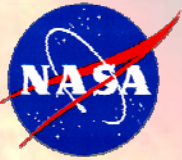
And besides that –
It's the right thing to do!



Mitigating the Adverse Impact of Technology Maturity

How do you perform a Technology Assessment (TA)?

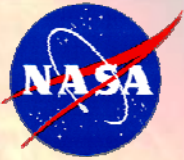
- There are many ways to perform Technology Assessments.
- The ensuing material describes one method that is essentially based on fundamental systems engineering principles.



Mitigating the Adverse Impact of Technology Maturity

What is Technology Assessment (TA)?

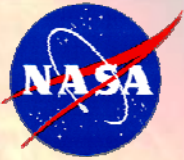
- It is a two-step process that involves:
 - The determination of the Technology Readiness Levels (TRLs) (i.e. current level of maturity).
 - The determination of the Advancement Degree of Difficulty (AD²) (i.e., what is required to advance a technology from its current TRL to what is required for infusion into the program/project at an acceptable level of risk.)



Mitigating the Adverse Impact of Technology Maturity

What is a Technology Readiness Level (TRL)?

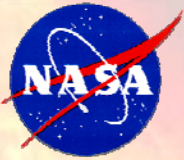
- At its most basic, the TRL is a description of the maturity of a given technology defined by what has been done, under what conditions at a given point in time.
- However, the TRL is just one part of the equation – and the initial assessment establishes the baseline for the program/project.
- The more fundamental question is what is required (in terms of cost, schedule and risk to move the technology from where it is to where it needs to be.



Mitigating the Adverse Impact of Technology Maturity

What is an Advancement Degree of Difficulty (AD²)?

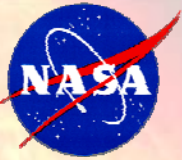
- **AD2** is a method of dealing with the other aspects beyond TRL, it is the description of what is required to move a technology from one TRL to another.
- It takes into account:
 - Design Readiness Level
 - Manufacturing Readiness Level (MRL)
 - Integration Readiness Level (IRL)
 - Software Readiness Level (SRL)
 - Operational Readiness Level
 - Human Readiness Levels (HRL) (skills)
 - Capability Readiness Levels (CRL) (people and tools)
 - organizational aspects (ability of an organization to reproduce existing technology)
 - Etc.



Mitigating the Adverse Impact of Technology Maturity

Technology Assessment (TA)

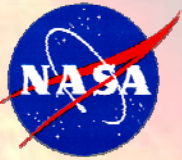
- It is extremely important that a Technology Assessment process be defined at the beginning of the program/project.
- It is also extremely important that it be performed at the earliest possible stage (concept development) and repeated periodically throughout the program/project through PDR.
- Inputs to the process will vary in level of detail according to the phase of the program/project in which it is conducted.



Mitigating the Adverse Impact of Technology Maturity

Technology Assessment (TA)

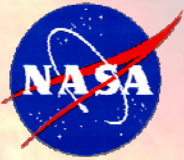
- Even though there is a lack of detail in pre-phase A, the TA will drive out the major critical technological advancements required.
- Therefore, at the beginning of pre-phase A, the following should be provided:
 - Refinement of Technology Readiness Level Definitions
 - Definition of Advancement Degree of Difficulty Process
 - Definition of terms to be used in the assessment process
 - Establishment of meaningful evaluation criteria and metrics that will allow for clear identification of gaps and shortfalls in performance.
 - Establishment of the TA team
 - Establishment of an independent TA review team.



Mitigating the Adverse Impact of Technology Maturity

Technology Assessment (TA)

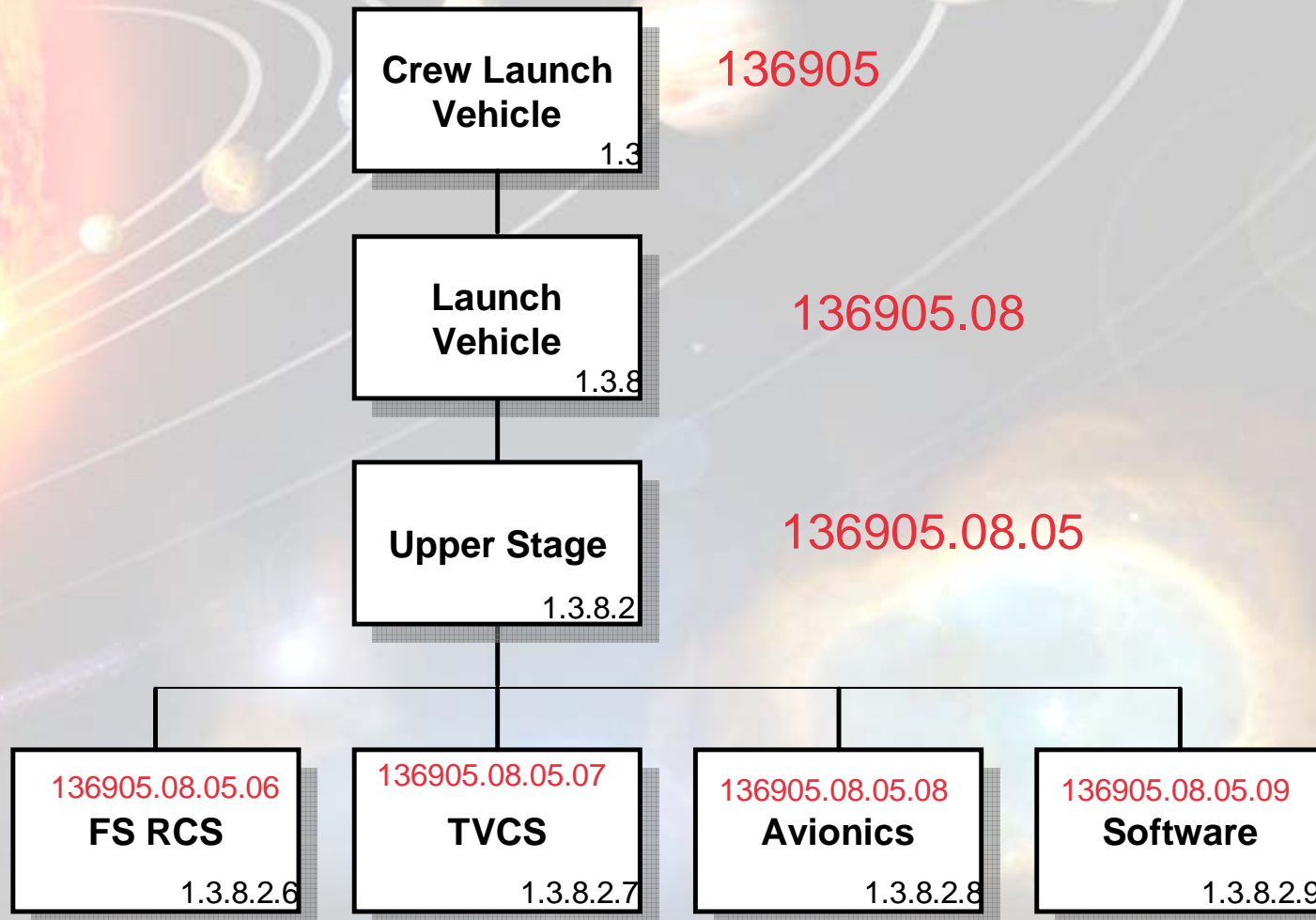
- **The complete TA should be repeated just prior to SRR to:**
 - establish the baseline maturity of the design and
 - To provide the material necessary to prepare the Technology Development Plan
- **A TRL assessment should be completed just prior to PDR to provide the material necessary to prepare the Technology Readiness Assessment Report**

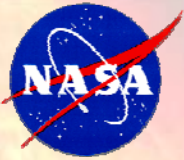


Mitigating the Adverse Impact of Technology Maturity

Technology Assessment

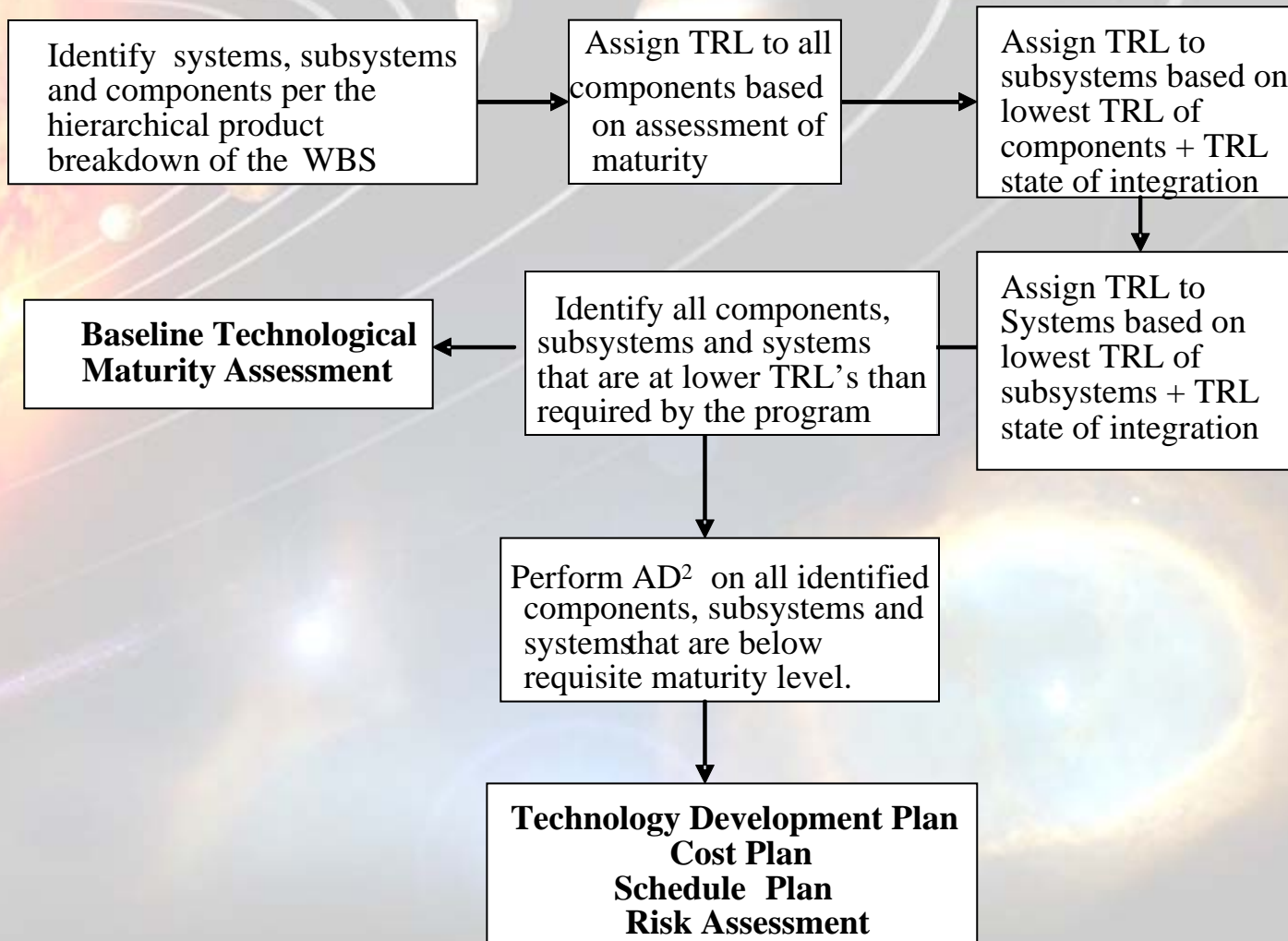
Start with the WBS

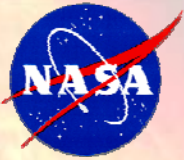




Mitigating the Adverse Impact of Technology Maturity

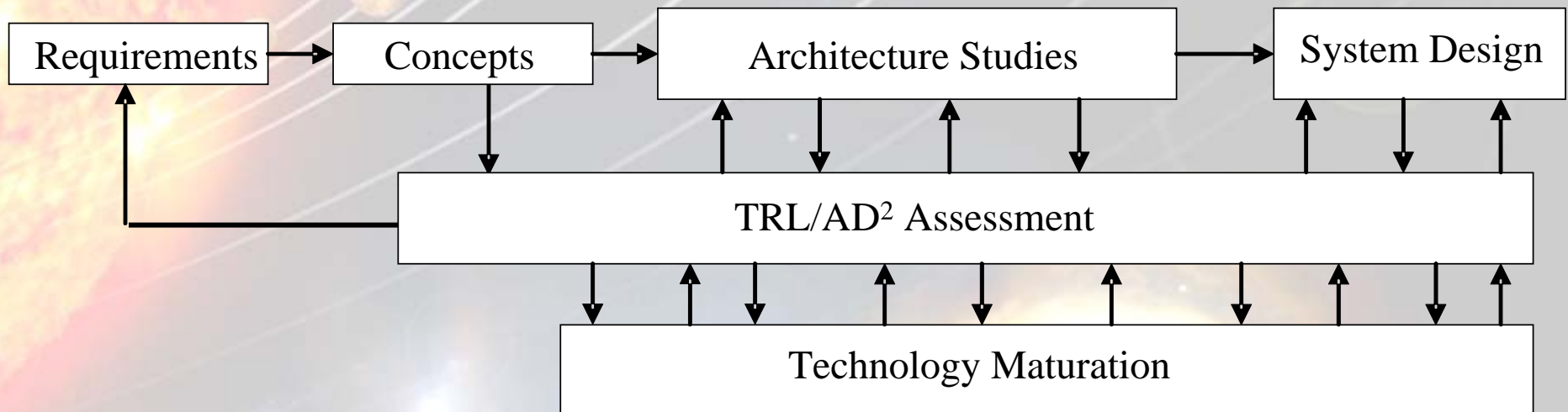
The Technology Assessment Process

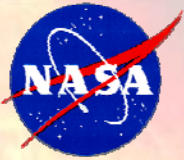




Mitigating the Adverse Impact of Technology Maturity

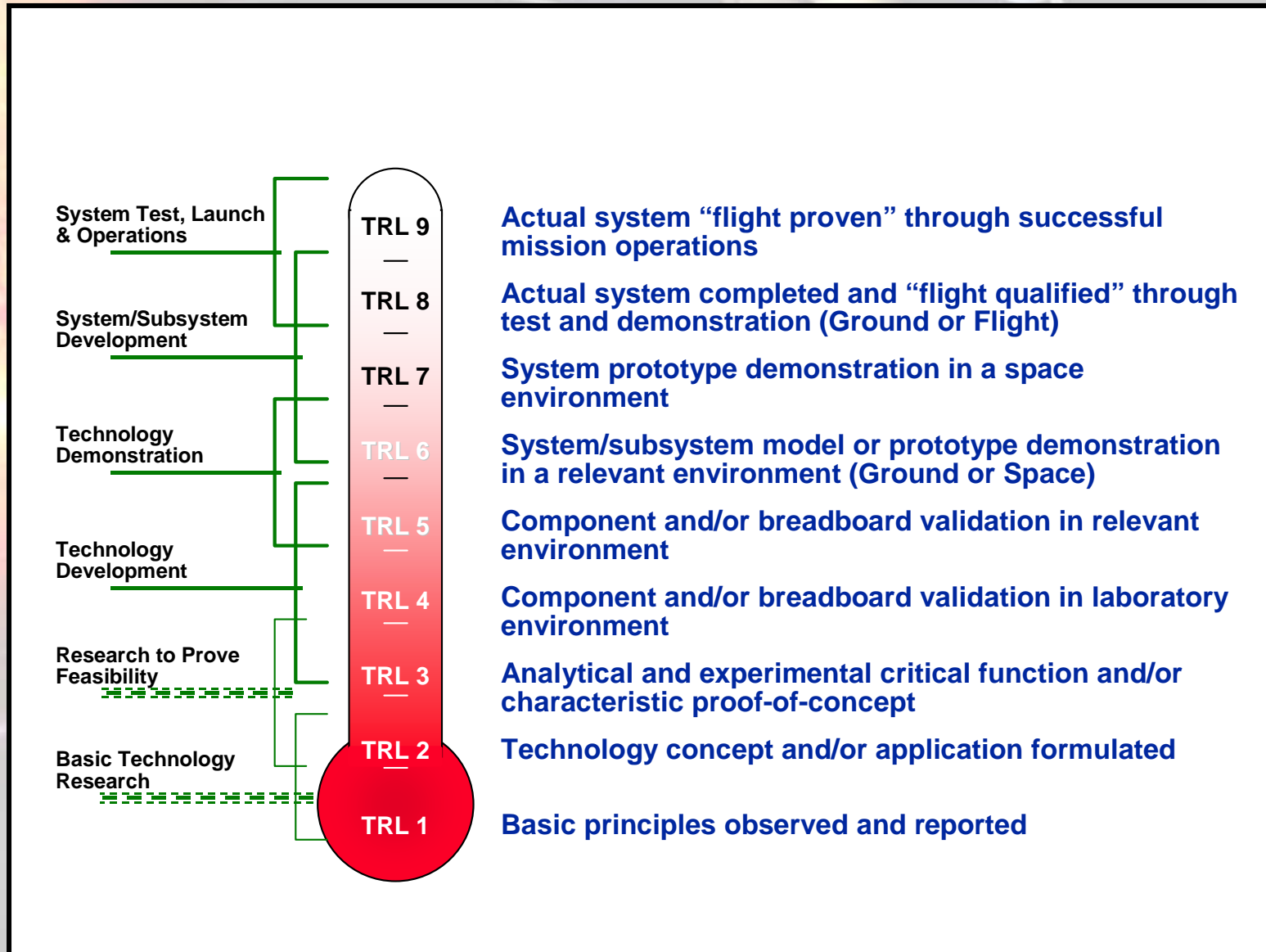
Architectural Study & Technology Assessment Interaction

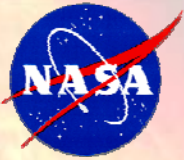




Mitigating the Adverse Impact of Technology Maturity

TRL Descriptions

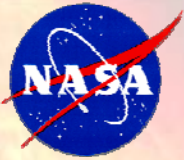




Mitigating the Adverse Impact of Technology Maturity

TRL Descriptions

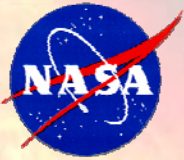
Technology Readiness Level - (TRL)	Definition	Hardware Description	Software Description	Exit Criteria
1	Basic principles observed and reported	Scientific knowledge generated underpinning hardware technology concepts/applications.	Scientific knowledge generated underpinning basic properties of software architecture and mathematical formulation.	Peer reviewed publication of research underlying the proposed concept/application
2	Technology concept or application formulated	Invention begins, practical application is identified but is speculative, no experimental proof or detailed analysis is available to support the conjecture.	Invention begins, practical application is identified but is speculative, no experimental proof or detailed analysis is available to support the conjecture. Underlying Algorithms are clarified and documented.	Documented description of the application/concept that addresses feasibility and benefit
3	Analytical and/or experimental critical function or characteristic proof-of-concept	Analytical studies place the technology in an appropriate context and laboratory demonstrations, modeling and simulation validate analytical prediction.	Development of limited functionality to validate critical properties and predictions using non-integrated software components	Documented analytical/experimental results validating predictions of key parameters



Mitigating the Adverse Impact of Technology Maturity

TRL Descriptions - continued

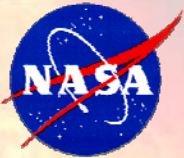
4	Component or breadboard validation in laboratory	A low fidelity system/component breadboard is built and operated to demonstrate basic functionality and critical test environments and associated performance predictions are defined relative to the final operating environment.	Key, functionally critical, software components are integrated, and functionally validated, to establish interoperability and begin architecture development. Relevant Environments defined and performance in this environment predicted.	Documented test performance demonstrating agreement with analytical predictions. Documented definition of relevant environment.
5	Component or breadboard validation in a relevant environment	A mid-level fidelity system/component brassboard is built and operated to demonstrate overall performance in a simulated operational environment with realistic support elements that demonstrates overall performance in critical areas. Performance predictions are made for subsequent development phases.	End to End Software elements implemented and interfaced with existing systems conforming to target environment, including the target o software environment. End to End Software System, Tested in Relevant Environment, Meets Predicted Performance. Operational Environment Performance Predicted.	Documented test performance demonstrating agreement with analytical predictions. Documented definition of scaling requirements
6	System/subsystem model or prototype demonstration in a relevant environment	A high-fidelity system/component prototype that adequately addresses all critical scaling issues is built and operated in a relevant environment to demonstrate operations under critical environmental conditions.	Prototype software partially integrated with existing hardware/software sytems and demonstrated on full-scale realistic problems.	Documented test performance demonstrating agreement with analytical predictions



Mitigating the Adverse Impact of Technology Maturity

TRL Descriptions - continued

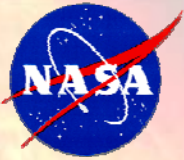
7	System prototype demonstration in space	A high fidelity engineering unit that adequately addresses all critical scaling issues is built and operated in a relevant environment to demonstrate performance in the actual operational environment and platform (ground, airborne or space).	Prototype software is fully integrated with operational hardware/software systems demonstrating operational feasibility.	Documented test performance demonstrating agreement with analytical predictions
8	Actual system completed and flight qualified through test and demonstration	The final product in its final configuration is successfully demonstrated through test and analysis for its intended operational environment and platform (ground, airborne or space).	The final product in its final configuration is successfully [demonstrated] through test and analysis for its intended operational environment and platform (ground, airborne or space).	Documented test performance verifying analytical predictions
9	Actual system flight proven through successful mission operations	The final product is successfully operated in an actual mission.	The final product is successfully operated in an actual mission.	Documented mission operational results



Mitigating the Adverse Impact of Technology Maturity

Definitions

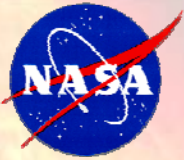
- **Proof of Concept: (TRL 3)**
Analytical and experimental demonstration of hardware/software concepts that may or may not be incorporated into subsequent development and/or operational units.
- **Breadboard: (TRL 4)**
A low fidelity unit that demonstrates function only, without respect to form or fit in the case of hardware, or platform in the case of software. It often uses commercial and/or ad hoc components and is not intended to provide definitive information regarding operational performance.
- **Developmental Model/ Developmental Test Model: (TRL 4)**
Any of a series of units built to evaluate various aspects of form, fit, function or any combination thereof. In general these units may have some high fidelity aspects but overall will be in the breadboard category.
- **Brassboard: (TRL 5 – TRL6)**
A mid-fidelity functional unit that typically tries to make use of as much operational hardware/software as possible and begins to address scaling issues associated with the operational system. It does not have the engineering pedigree in all aspects, but is structured to be able to operate in simulated operational environments in order to assess performance of critical functions.



Mitigating the Adverse Impact of Technology Maturity

Definitions - continued

- **Mass Model: (TRL 5)**
Nonfunctional hardware that demonstrates form and/or fit for use in interface testing, handling, and modal anchoring.
- **Subscale model: (TRL 5 – TRL7)**
Hardware demonstrated in subscale to reduce cost and address critical aspects of the final system. If done at a scale that is adequate to address final system performance issue it may become the prototype.
- **Proof Model: (TRL 6)**
Hardware built for functional validation up to the breaking point, usually associated with fluid system over pressure, vibration, force loads, environmental extremes, and other mechanical stresses.



Mitigating the Adverse Impact of Technology Maturity

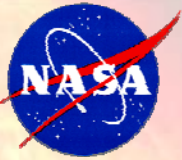
Definitions - continued

- **Proto-type Unit: (TRL 6 – TRL 7)**

The proto-type unit demonstrates form (shape and interfaces), fit (must be at a scale to adequately address critical full size issues), and function (full performance capability) of the final hardware. It can be considered as the first Engineering Model. It does not have the engineering pedigree or data to support its use in environments outside of a controlled laboratory environment – except for instances where a specific environment is required to enable the functional operation including in-space. It is to the maximum extent possible identical to flight hardware/software and is built to test the manufacturing and testing processes at a scale that is appropriate to address critical full scale issues.

- **Engineering Model: (TRL 6 – TRL 8)**

A full scale high-fidelity unit that demonstrates critical aspects of the engineering processes involved in the development of the operational unit. It demonstrates function, form, fit or any combination thereof at a scale that is deemed to be representative of the final product operating in its operational environment. Engineering test units are intended to closely resemble the final product (hardware/software) to the maximum extent possible and are built and tested so as to establish confidence that the design will function in the expected environments. In some cases, the engineering unit will become the protoflight or final product, assuming proper traceability has been exercised over the components and hardware handling.



Mitigating the Adverse Impact of Technology Maturity Definitions - continued

- **Flight Qualification Unit: (TRL 8)**

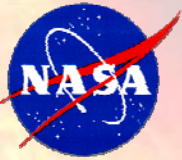
Flight hardware that is tested to the levels that demonstrate the desired margins, particularly for exposing fatigue stress., typically 20-30%. Sometimes this means testing to failure. This unit is never flown. Key overtest levels are usually +6db above maximum expected for 3 minutes in all axes for shock, acoustic, and vibration; thermal vacuum 10C beyond acceptance for 6 cycles, and 1.25 times static load for unmanned flight.

- **Protoflight Unit: (TRL 8 – TRL 9)**

Hardware built for the flight mission that includes the lessons learned from the Engineering Model but where no Qualification model was built to reduce cost. It is however tested to enhanced environmental acceptance levels. It becomes the mission flight article. A higher risk tolerance is accepted as a tradeoff. Key protoflight overtest levels are usually +3db for shock, vibration, and acoustic; 5C beyond acceptance levels for thermal vacuum tests.

- **Flight Qualified Unit: (TRL8 – TRL9)**

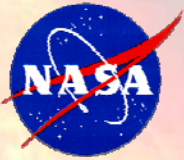
Actual flight hardware/software that has been through acceptance testing. Acceptance test levels are designed to demonstrate flight-worthiness, to screen for infant failures without degrading performance. The levels are typically less than anticipated levels.



Mitigating the Adverse Impact of Technology Maturity

Definitions - continued

- **Flight Proven: (TRL 9)**
Hardware/software that is identical to hardware/software that has been successfully operated in a space mission and that is being used in an identical architecture under identical operational environments.



Mitigating the Adverse Impact of Technology Maturity

Definitions - continued

- **Laboratory Environment:**

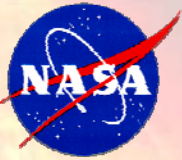
An environment that does not address in any manner the environment to be encountered by the system, subsystem or component (hardware or software) during its intended operation. Tests in a laboratory environment are solely for the purpose of demonstrating the underlying principles of technical performance (functions) without respect to the impact of environment.

- **Relevant Environment:**

Not all systems, subsystems and/or components need to be operated in the operational environment in order to satisfactorily address performance margin requirements. Consequently, the relevant environment is the specific subset of the operational environment that is required to demonstrate critical “at risk” aspects of the final product performance in an operational environment.

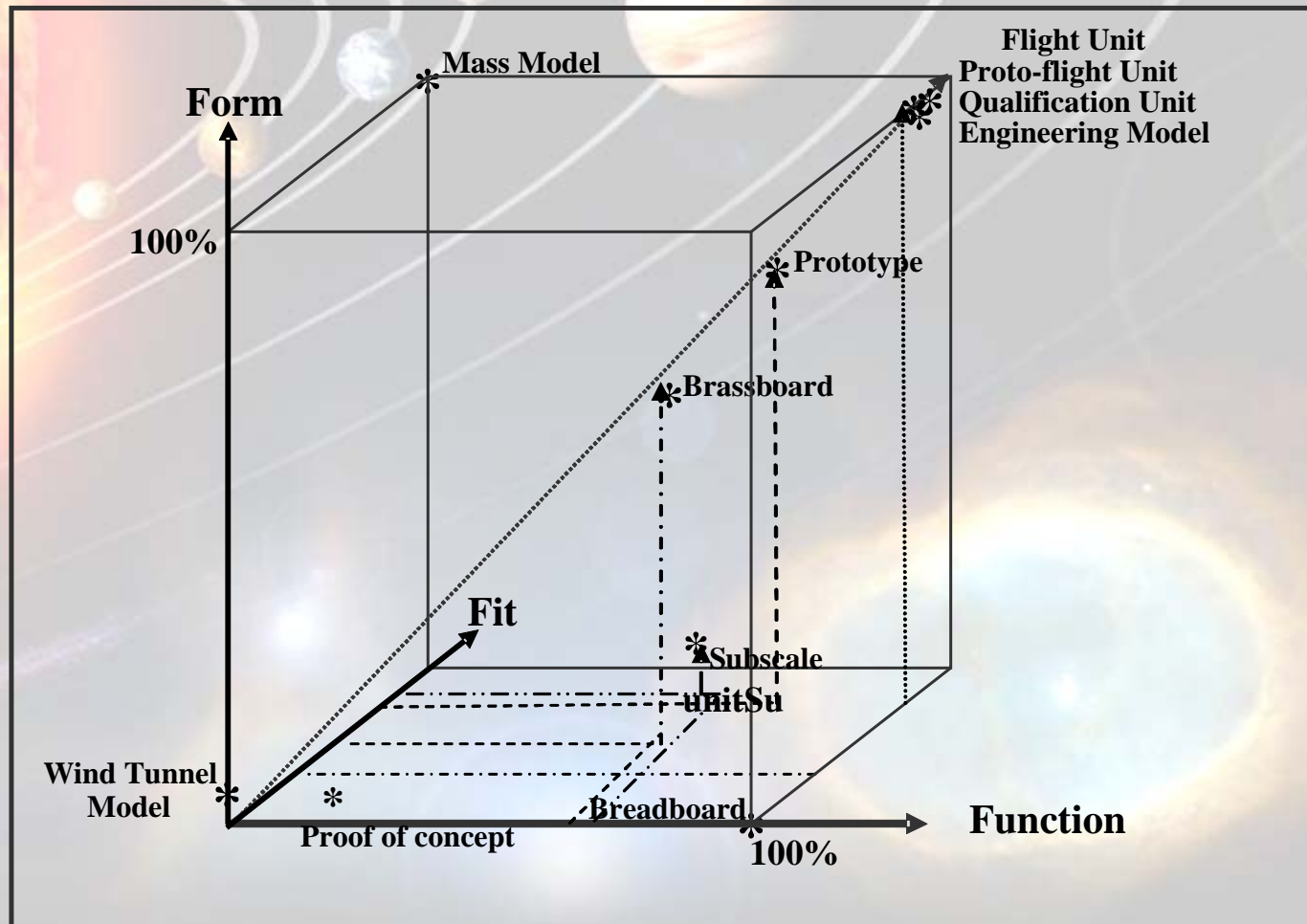
- **Operational Environment:**

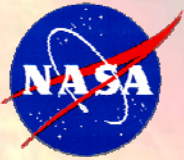
The environment in which the final product will be operated. In the case of spaceflight hardware/software it is space. In the case of ground based or airborne systems that are not directed toward space flight it will be the environments defined by the scope of operations. For software, the environment will be defined by the operational platform and software operating system.



Mitigating the Adverse Impact of Technology Maturity

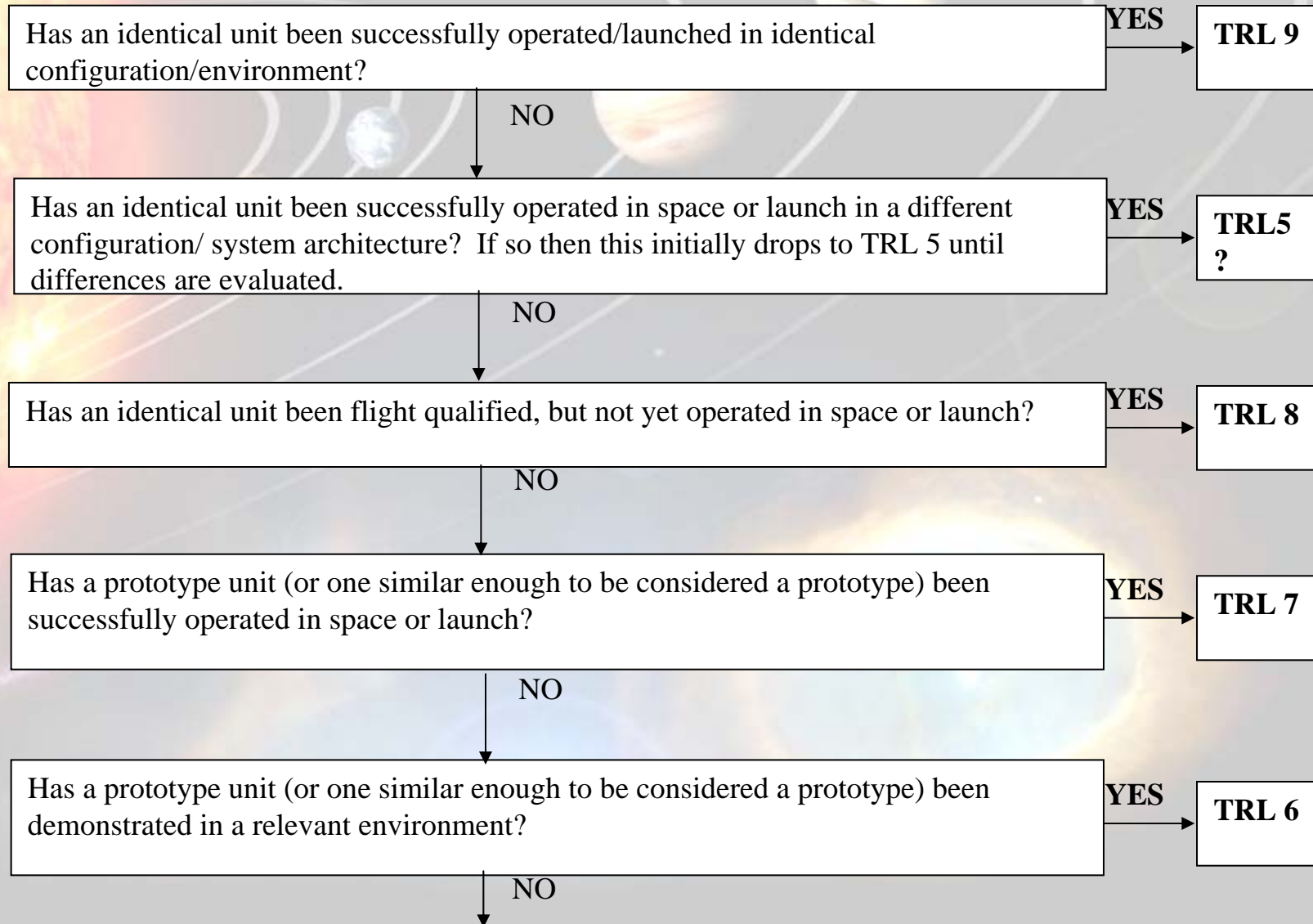
Form Fit & Function Definitions

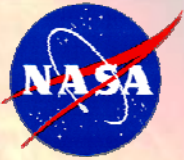




Mitigating the Adverse Impact of Technology Maturity

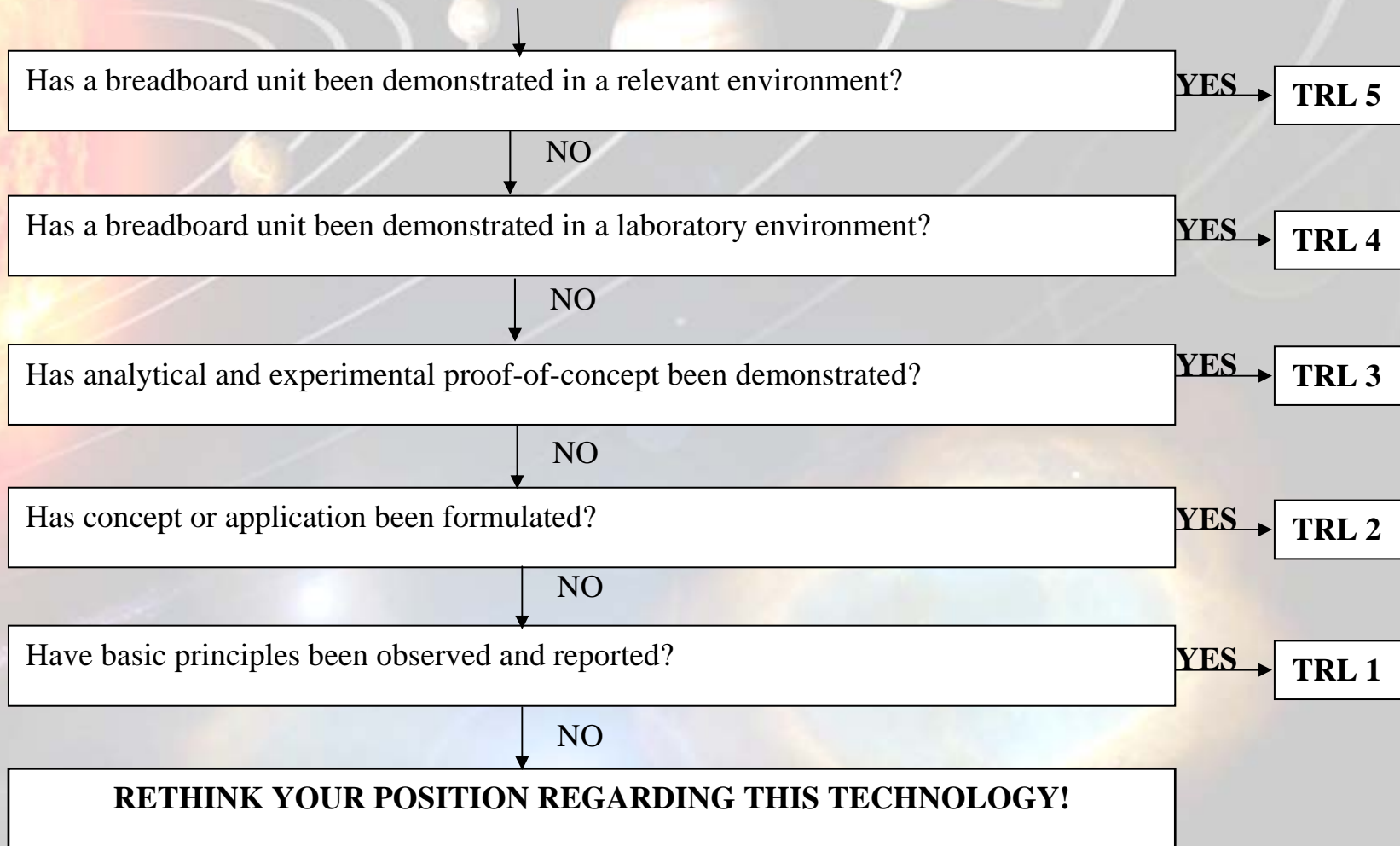
TRL Assessment Thought Process

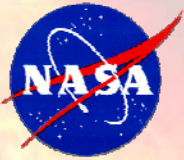




Mitigating the Adverse Impact of Technology Maturity

TRL Assessment Thought Process

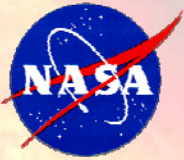




Mitigating the Adverse Impact of Technology Maturity

TRL Assessment Matrix

TRL Assessment														
	Concept	Demonstration Units					Environment			Unit Description				Overall TRL
		Breadboard	Brassboard	Developmental Model	Prototype	Flight Qualified	Laboratory Environment	Relevant Environment	Space Environment	Space/Launch Operation	Form	Fit	Function	
1.0 System														
1.1 Subsystem X														
1.1.1 Mechanical Components														
1.1.2 Mechanical Systems														
1.1.3 Electrical Components				X				X		X	X	X		
1.1.4 Electrical Systems														
1.1.5 Control Systems														
1.1.6 Thermal Systems						X				X	X			
1.1.7 Fluid Systems		X												
1.1.8 Optical Systems														
1.1.9 Electro-optical Systems														
1.1.10 Software Systems														
1.1.11 Mechanisms	X													
1.1.12 Integration														
1.2 Subsystem Y														
1.2.1 Mechanical Components														



Mitigating the Adverse Impact of Technology Maturity

TRL Calculator

Main Menu
TRL Calculator
Release Notes

1


AFRL Hardware and Software Transition Readiness Level Calculator, Version 2.2

This worksheet summarizes the TRL Calculator results. It displays the TRL, MRL, and PRL computed elsewhere. You may select the technology types and TRL categories (elements) you wish to include here or on the Calculator worksheet. Choose Hardware, Software, or Both to fit your program. If you omit a category of readiness level, (TRL, MRL, or PRL) that calculation is removed from the summary. The box in front of each readiness level element is checked when that category is included in the summary.

You can enter program identification information here, too.
TRL documentation including discussions of TRL, MRL, and PRL is available from the Main Menu.

<input type="checkbox"/>	<input type="radio"/>	Include Hardware Only
<input type="checkbox"/>	<input type="radio"/>	Include Software Only
<input checked="" type="checkbox"/>	<input checked="" type="radio"/>	Include Hardware and Software

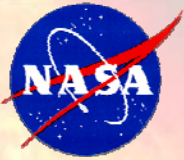
<input checked="" type="checkbox"/>	<input checked="" type="radio"/>	Technology Readiness Level
<input type="checkbox"/>	<input type="radio"/>	Manufacturing Readiness Level
<input checked="" type="checkbox"/>	<input checked="" type="radio"/>	Programmatic Readiness Level



Green / Yellow set points: Here you can change the default values the spreadsheet uses to determine which color to award at a given level of question completion. System defaults are 100% for Green, and 67% for Yellow. You can change these set points to any value above 75% for Green, and any value from 50% to 85% for Yellow; however, the Yellow set point will always be at least 15% below the Green set point. Use the spinners to set your desired values. The defaults kick in if you try to set a value less than the minimum values of 75% for Green and 50% for Yellow. Start with the "Up" arrow to change defaults.

Green set point is now at:
▲▼
100%

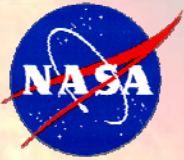
Yellow set point is now at:
▲▼
67%



Mitigating the Adverse Impact of Technology Maturity

TRL Calculator Example

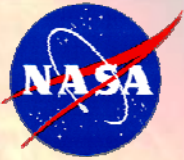
WBS	Element Name	Assessed Area	TRL Score			MRL Score	
			5	6	7	5	6
136905.08.05.03	Structure & Thermal	a) Primary Structure	5	6	7	5	
		b) Secondary Structure	5	6	7	5	6
		c) Flight Separation System	5	6,7	8	5	7
		d) TPS	5	6,7	8	6	7
136905.08.05.04	Main Propulsion System	a) Ducts & Lines	5	6	7	5	6
		b) Valves & Actuators	5	6	7	5	6
136905.08.05.05	US Reaction Control System		5	6,7	8	5	7
136905.08.05.06	1st Stage Reaction Control System		5	6,7	8	5	7
136905.08.05.07	Thrust Vector Control	a) Actuators	5	6	7	5	6
		b) Hydraulic Power Systems	4	5,6	7	5	6
136905.08.05.08	Avionics	a) C&DH	4	5,6	7	5	6
		b) GNC Hardware	5	6	7	6	
		c) Electrical Power	6	7		6	7
		d) Sensors	6	7		6	7
136905.08.05.09	Flight Software System		4	5	6	4	5
136905.08.05.10	Component Integration & Test		Not Applicable				
136905.08.05.11	Logistics Support Infrastructure	GSE	6	7	8	6	7
136905.08.05.12	Manufacturing and Assembly	Tooling	5	6,7	8	6	7



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TRL Revised Questions

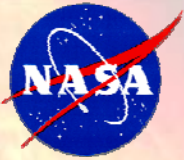
TRL 5	1	Critical functions and associated subsystems and components identified?
	2	Relevant environments finalized?
	3	Scaling requirements defined & documented?
	4	Critical subsystems and components breadboards/brassboards identified and designed?
	5	Subsystem/component breadboards/brassboards built?
	6	Facilities, GSE, STE available to support testing in a relevant environment?
	7	M&S performance predictions completed?
	8	System level performance predictions made for subsequent development phases?
	9	Breadboards/brassboards successfully demonstrated in a relevant environment?
	10	Successful demonstration documented along with scaling requirements?
TRL 6	1	System requirements finalized?
	2	Operating environment definition finalized?
	3	Subset of relevant environments identified that address key aspects of the final operating environment?
	4	M&S used to simulate system performance in an operational environment?
	5	M&S used to simulate system/subsystem engineering model/prototype performance in the relevant environment?
	6	External interfaces baselined?
	7	Scaling requirements finalized?
	8	Facilities, GSE, STE available to support system/subsystem engineering model/prototype testing in the relevant environment?
	9	System/subsystem engineering model/prototype that adequately addresses critical scaling
	10	System/subsystem engineering model/prototype that adequately addresses critical scaling issues tested in the relevant environment?
	11	Analysis of test results verify performance predictions for relevant environment?
	12	Test performance demonstrating agreement with performance predictions documented?



Mitigating the Adverse Impact of Technology Maturity

Advancement Degree of Difficulty AD²

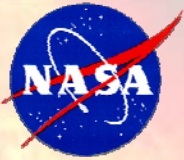
Degree of Difficulty	Description
9	0% Development Risk - Exists with no or only minor modifications being required. A single development approach is adequate.
8	10% Development Risk - Exists but requires major modifications. A single development approach is adequate.
7	20% Development Risk - Requires new development well within the experience base. A single development approach is adequate.
6	30% Development Risk - Requires new development but similarity to existing experience is sufficient to warrant comparison across the board. A single development approach can be taken with a high degree of confidence for success.
5	40% Development Risk - Requires new development but similarity to existing experience is sufficient to warrant comparison in all critical areas. Dual development approaches should be pursued to provide a high degree of confidence for success.



Mitigating the Adverse Impact of Technology Maturity

Advancement Degree of Difficulty AD² - continued

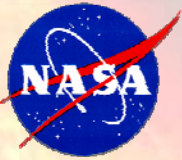
4	50% Development Risk - Requires new development but similarity to existing experience is sufficient to warrant comparison in only a subset of critical areas. Dual development approaches should be pursued in order to achieve a moderate degree of confidence for success. (Desired performance can be achieved in subsequent block upgrades with high degree of confidence.)
3	60% Development Risk - Requires new development but similarity to existing experience is sufficient to warrant comparison in only a subset of critical areas. Multiple development routes must be pursued.
2	80% Development Risk - Requires new development where similarity to existing experience base can be defined only in the broadest sense. Multiple development routes must be pursued.
1	100% Development Risk - Requires new development outside of any existing experience base. No viable approaches exist that can be pursued with any degree of confidence. Basic research in key areas needed before feasible approaches can be defined.



Mitigating the Adverse Impact of Technology Maturity

Design and Analysis

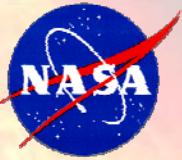
- Do the necessary data bases exist and if not, what level of development is required to produce them?
- Do the necessary design methods exist and if not, what level of development is required to produce them?
- Do the necessary design tools exist and if not, what level of development is required to produce them?
- Do the necessary analytical methods exist and if not, what level of development is required to produce them?
- Do the necessary analysis tools exist and if not, what level of development is required to produce them?
- Do the appropriate models with sufficient accuracy exist and if not, what level of development is required to produce them?
- Do the available personnel have the appropriate skills and if not, what level of development is required to acquire them?
- Has the design been optimized for manufacturability and if not, what level of development is required to optimize it?
- Has the design been optimized for testability and if not, what level of development is required to optimize it?



Mitigating the Adverse Impact of Technology Maturity

Manufacturing

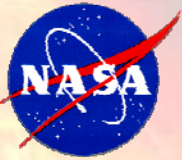
- Do the necessary materials exist and if not, what level of development is required to produce them?
- Do the necessary manufacturing facilities exist and if not, what level of development is required to produce them?
- Do the necessary manufacturing machines exist and if not, what level of development is required to produce them?
- Does the necessary manufacturing tooling exist and if not, what level of development is required to produce it?
- Does the necessary metrology exist and if not, what level of development is required to produce it?
- Does the necessary manufacturing software exist and if not, what level of development is required to produce it?
- Do the available personnel have the appropriate skills and if not, what level of development is required to acquire them?
- Has the design been optimized for manufacturability and if not, what level of development is required to optimize it?
- Has the manufacturing process flow been optimized and if not, what level of development is required to optimize it?
- Has the manufacturing process variability been minimized and if not, what level of development is required to optimize it?



Mitigating the Adverse Impact of Technology Maturity

Manufacturing – continued

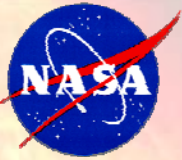
- Has the design been optimized for reproducibility and if not, what level of development is required to optimize it?
- Has the design been optimized for assembly & alignment and if not, what level of development is required to optimize it?
- Has the design been optimized for integration at the component, subsystem and system level and if not, what level of development is required to optimize it?
- Are breadboards required and if so what level of development is required to produce them?
- Are brassboards required and if so what level of development is required to produce them?
- Are subscale models required and if so what level of development is required to produce them?
- Are engineering models required and if so what level of development is required to produce them?
- Are prototypes required and if so what level of development is required to produce them?
- Are breadboards, brassboards, engineering models and prototypes at the appropriate scale and fidelity for what they are to demonstrate, and if not what level of development is required to modify them accordingly?
- Are Qualification models required and if so what level of development is required to produce them?



Mitigating the Adverse Impact of Technology Maturity

Operations

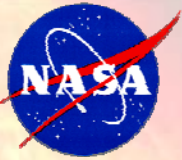
- Has the design been optimized for maintainability and servicing and if not, what level of development is required to optimize it?
- Has the design been optimized for minimum life cycle cost and if not, what level of development is required to optimize it?
- Has the design been optimized for minimum annual recurring / operational cost and if not, what level of development is required to optimize it?
- Has the design been optimized for reliability and if not, what level of development is required to optimize it?
- Has the design been optimized for availability {ratio of operating time (reliability) to downtime (maintainability/ supportability)} and if not, what level of development is required to optimize it?
- Do the necessary ground systems facilities & infrastructure exist and if not, what level of development is required to produce them?
- Does the necessary ground systems equipment exist and if not, what level of development is required to produce it?
- Does the necessary ground systems software exist and if not, what level of development is required to produce it?
- Do the available personnel have the appropriate skills and if not, what level of development is required to acquire them?



Mitigating the Adverse Impact of Technology Maturity

Test & Evaluation

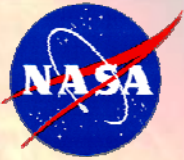
- Do the necessary test facilities exist and if not, what level of development is required to produce them?
- Does the necessary test equipment exist and if not, what level of development is required to produce them?
- Does the necessary test tooling exist and if not, what level of development is required to produce it?
- Do the necessary test measurement systems exist and if not, what level of development is required to produce them?
- Does the necessary software exist and if not, what level of development is required to produce it?
- Do the available personnel have the appropriate skills and if not, what level of development is required to acquire them?
- Has the design been optimized for testability and if not, what level of development is required to optimize it?
- Are breadboards required to be tested and if so what level of development is required to test them?
- Are brassboards required to be tested and if so what level of development is required to test them?



Mitigating the Adverse Impact of Technology Maturity

Test & Evaluation – continued

- Are subscale models required to be tested and if so what level of development is required to test them?
- Are engineering models required to be tested and if so what level of development is required to test them?
- Are prototypes required to be tested and if so what level of development is required to test them?
- Are Qualification models required to be tested and if so what level of development is required to test them?



Mitigating the Adverse Impact of Technology Maturity

AD² Automated Format

Advancement Degree of Difficulty - Questions

2/7/07 11:45 AM

12/3/2006

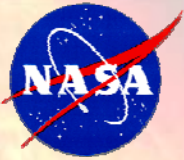
Title:

Evaluator:

WBS Product Hierarchy	Name	WBS#, use multiple decimal points
System	<input type="text"/>	<input type="text"/>
Subsystem	<input type="text"/>	<input type="text"/>
Component	<input type="text"/>	<input type="text"/>

Only Answer Those Questions That Apply

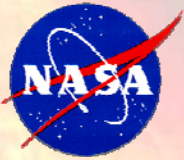
Schedule	Cost	Technical Deg Of Difficulty	Design and Analysis	Comments (42 character limit)
<input type="text"/>	<input type="text"/>	<input type="text"/>	Do the necessary <u>data bases</u> exist and if not, what level of development is required to produce them?	
<input type="text"/>	<input type="text"/>	<input type="text"/>	Do the necessary <u>design methods</u> exist and if not, what level of development is required to produce them?	
<input type="text"/>	<input type="text"/>	<input type="text"/>	Do the necessary <u>design tools</u> exist and if not, what level of development is required to produce them?	
<input type="text"/>	<input type="text"/>	<input type="text"/>	Do the necessary <u>analytical methods</u> exist and if not, what level of development is required to produce them?	
<input type="text"/>	<input type="text"/>	<input type="text"/>	Do the necessary <u>analysis tools</u> exist and if not, what level of development is required to produce them?	
<input type="text"/>	<input type="text"/>	<input type="text"/>	Do the appropriate <u>models</u> with sufficient accuracy exist and if not, what level of development is required to produce them?	
<input type="text"/>	<input type="text"/>	<input type="text"/>	Do the available <u>personnel</u> have the appropriate skills and if not, what level of development is required to acquire them?	
<input type="text"/>	<input type="text"/>	<input type="text"/>	Has the design been optimized for <u>manufacturability</u> and if not, what level of development is required to optimize it?	
<input type="text"/>	<input type="text"/>	<input type="text"/>	Has the design been optimized for <u>testability</u> and if not, what level of development is required to optimize it?	



Mitigating the Adverse Impact of Technology Maturity

Summary

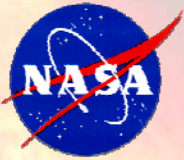
- The TRL assessment provides the baseline maturity at the start of a program/project and is the basis for the preparation of the Technology Readiness Assessment Report.
- The AD2 assessment provides the basis for the development of the Technology Development Plan.
- It also can provide considerable detail for more accurate determination of program cost and schedule.
 - The identification of data bases, tools, processes, facilities tests, scale model development and integration issues in particular will assist in developing realistic cost plans.
 - The identification of requirements for engineering model development and subsequent tests will be of particular benefit in outlining realistic schedules.
- Both processes can significantly contribute to ensuring program/project success.



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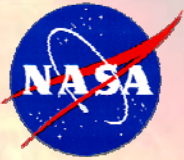
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