National Aeronautics and Space Administration

OSMA's Emerging Digital "Assurance Case" Framework

NEPP 2022

Presented by: Tony DiVenti, NASA R&M Technical Fellow

Acknowledgements: Homayoon Dezfulli, John Evans, Jeannette Plante and Frank Groen/NASA HQ; Ewen Denny & Ganesh Pai/NASA ARC and KBR; Steve Cornford, Martin Feather, and Todd Paulos/NASA JPL; Rebekah Austin and Ken LaBel/GSFC; Arthur Witulski, Nag Mahadevan, Gabor Karsai, Brian Sierawski, Robert Reed, and Ron Schrimpf/VU

Outline

- **What do we mean by Safety and Assurance Cases**
  - Descriptions
  - Broad Adoption
  - Definitions and Shaping Concepts
  - Conceptual Illustration
- **Other NASA Building Blocks**
  - R&M GSN/Objectives Hierarchy Application
  - NASA and VU GSN Application to Radiation Assurance Case (SEAM)
  - QA Ontology Framework
  - Objectives-driven, case-assured approach, S&MS Approach
- **OSMA's Emerging Digital "Objectives Hierarchy/Assurance Case" Framework**
  - Automated Program Plan Generator (APPG)
  - Digital On-Ramp to a NASA Interoperable, Enterprise, Environment

What do we mean by Safety and Assurance Cases

Safety (Assurance) Case Descriptions

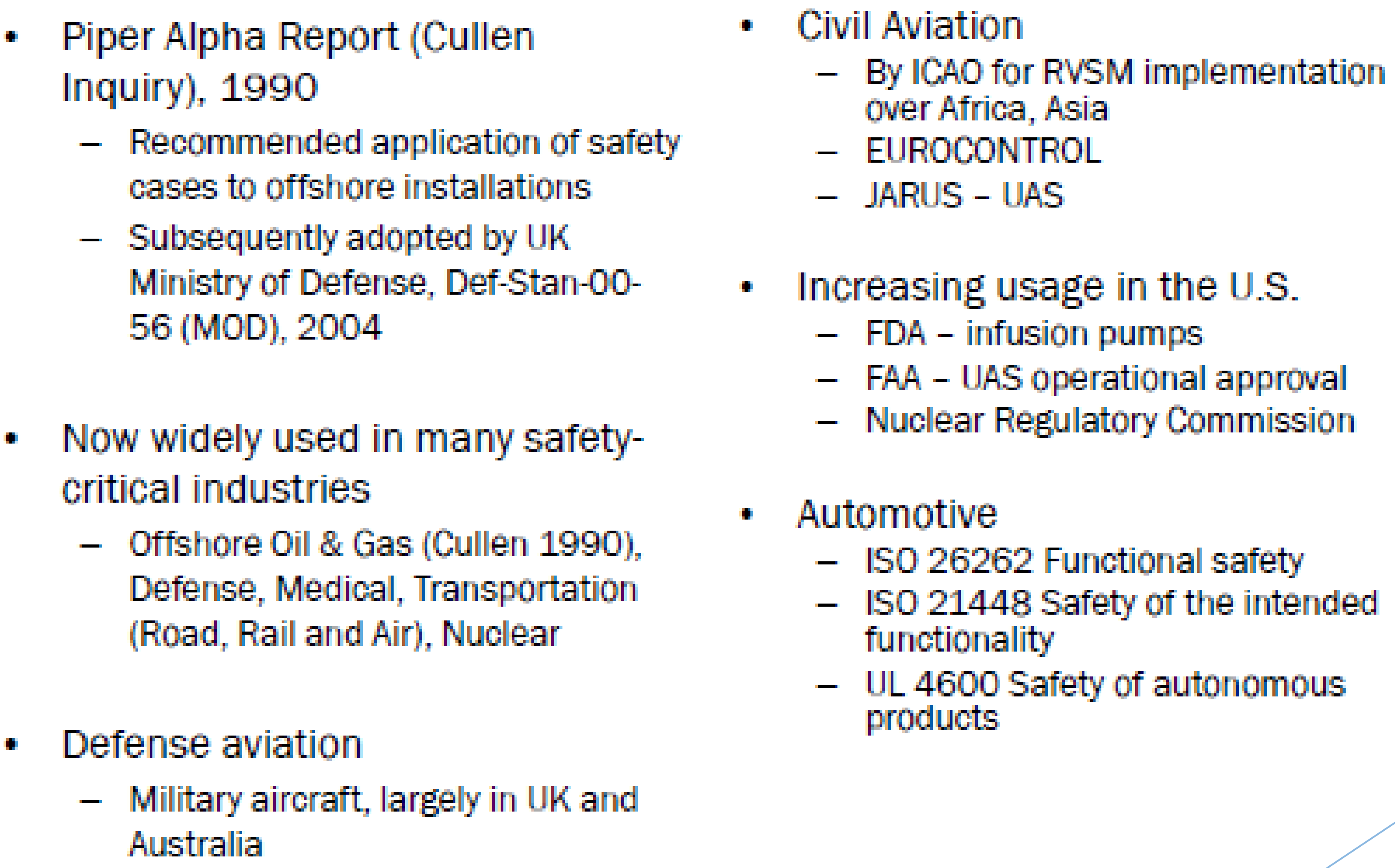
- Comprehensive, auditable, safety risk management artifact

- Authoritative record that
  - Safety risks have been identified, are well understood
  - Processes and mechanisms in place for risk reduction
    - Driver for development

- Explicit claims and evidence connected by rationale (argumentation)

- Properties
  - Compelling, comprehensive, convincing, valid, justifiable, defensible, ...

Broad Adoption



- Piper Alpha Report (Cullen Inquiry), 1990
  - Recommended application of safety cases to offshore installations
  - Subsequently adopted by UK Ministry of Defense, Def-Stan-00-56 (MOD), 2004
- Now widely used in many safety-critical industries
  - Offshore Oil & Gas (Cullen 1990), Defense, Medical, Transportation (Road, Rail and Air), Nuclear
- Defense aviation
  - Military aircraft, largely in UK and Australia
- Civil Aviation
  - By ICAO for RVSM implementation over Africa, Asia
  - EUROCONTROL
  - JARUS – UAS
- Increasing usage in the U.S.
  - FDA – infusion pumps
  - FAA – UAS operational approval
  - Nuclear Regulatory Commission
- Automotive
  - ISO 26262 Functional safety
  - ISO 21448 Safety of the intended functionality
  - UL 4600 Safety of autonomous products

Definitions and Shaping Concepts

NASA System Safety Handbook- Vol 1 (2011), (H. Dezfuli et al) – "The safety case concept has also been extended to apply to additional system attributes beyond just safety, resulting in **"Assurance Cases"** and "Dependability Cases"

Safety Case (reference Wikipedia) – A **structured argument**, supported by evidence, intended to justify that a system is acceptable safe for a specific application in a specific operating environment.

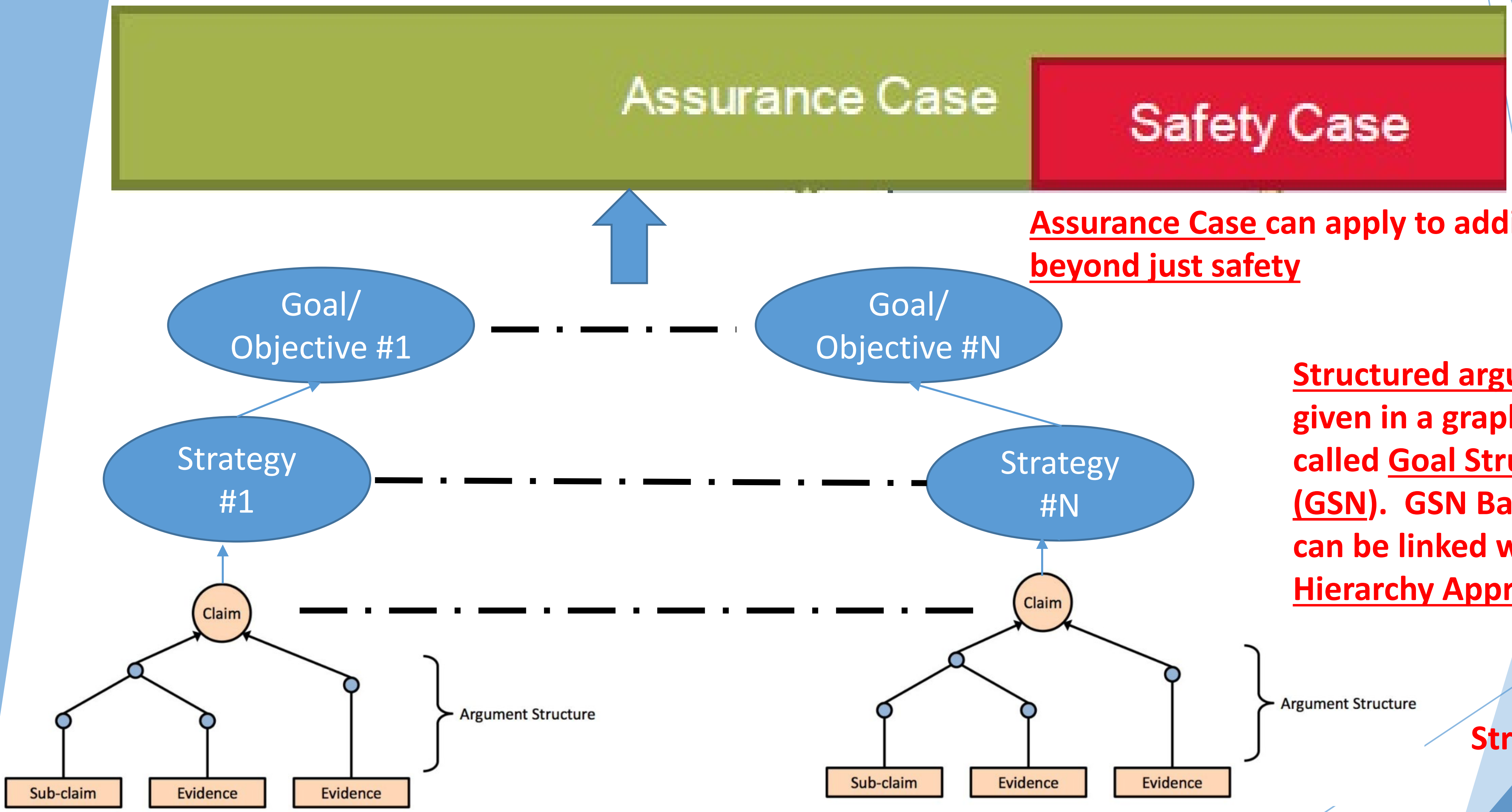
Assurance Case (reference "A Short Introduction to Assurance Cases, University of York, 2013) – A reasoned and compelling argument, supported by a body of evidence, that a *System,* Service, or organization **will operate as intended for a defined application in a defined environment.**

New Tool for Developing Safety Assurance Case Arguments (OSMA Article, 2020), (Ewen Denny and Ganesh Pai/ARC's KBR Wyle Services) –

"Traditionally, a safety case is a static thing," said Denney. "But really, what ***it should be is an active [framework]*** you use to govern your activities, so you update it when you learn more about…......the effectiveness of your mitigations and so on"

"The **structured arguments** are given in a graphical notation called ***Goal Structuring Notation (GSN)***, which has elements for capturing claims, reasoning strategies, evidence and contextual information. GSN-based arguments have close connections to the ***objective hierarchy's*** approach promulgated by NASA's Office of Safety and Mission Assurance."

Conceptual Illustration



Assurance Case can apply to additional system attributes beyond just safety

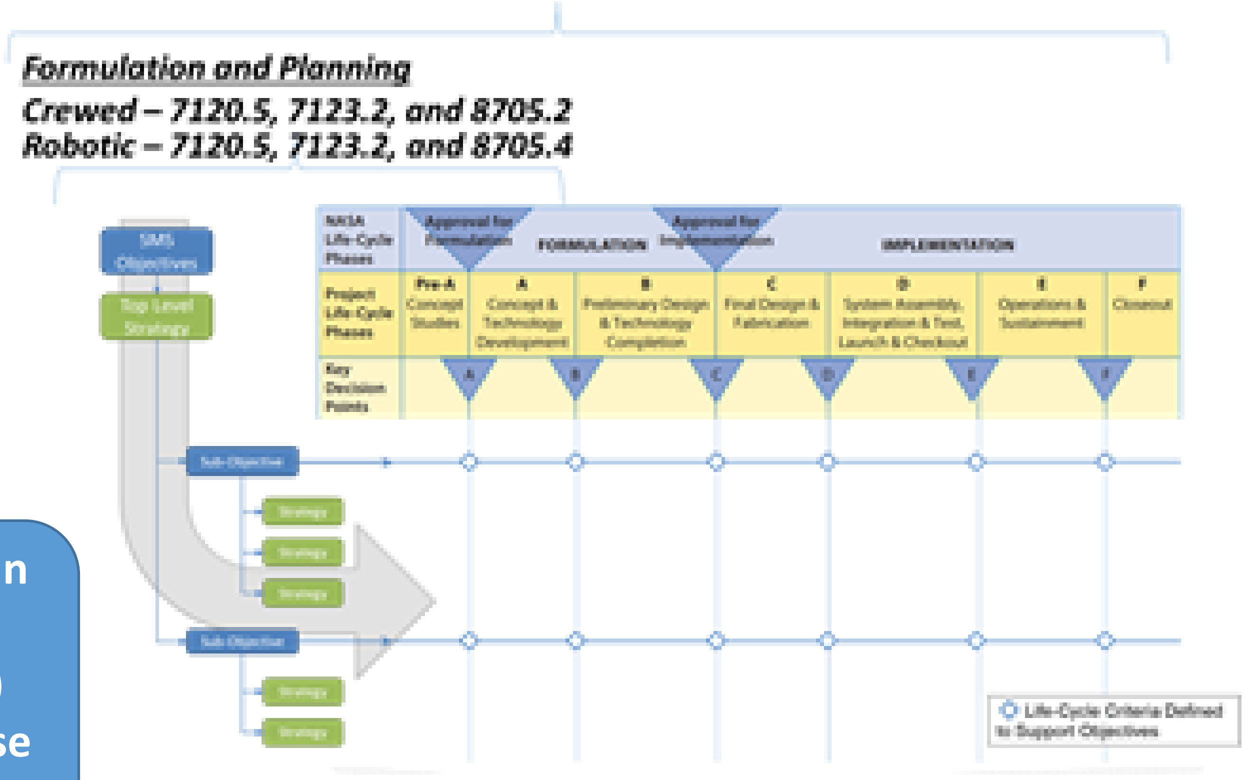
Structured arguments can be given in a graphical notation called Goal Structure Notation (GSN). GSN Based Arguments can be linked with an Objectives Hierarchy Approach.

Structured argument

SMA Digital Future – Objectives Hierarchy/Assurance Case Framework

Objectives Hierarchy
Objective Driven Reqts & Accepted STDs

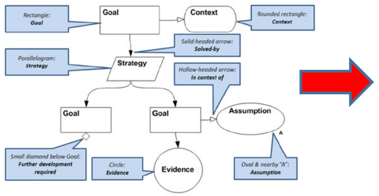
APPG AIM & SMA Plan Generation
(part of Project Plan)
INITIAL Assurance Case Argument



Formulation and Planning
Crewed – 7120.5, 7123.2, and 8705.2
Robotic – 7120.5, 7123.2, and 8705.4

NASA Life-Cycle Phases	Approval for Formulation	FORMULATION		Approval for Implementation	IMPLEMENTATION			
Project Life-Cycle Phases	Pre-A Concept Studies	A Concept & Technology Development	B Preliminary Design & Technology Completion	C Final Design & Fabrication	D System Assembly, Integration & Test, Launch & Checkout	E Operations & Sustainment	F Closeout	
Key Decision Points	A	B	C	D	E	F		

Design Assurance Case



Rectangle: Goal
Goal
Context
Rounded rectangle: Context
Solid-headed arrow: Solved-by
Parallelogram: Strategy
Strategy
Hollow-headed arrow: In context of
Goal
Goal
Assumption
A
Small diamond below Goal: Further development required
Circle: Evidence
Evidence
Oval & nearby "A": Assumption

I&T Assurance Case

Rectangle: Goal
Goal
Context
Rounded rectangle: Context
Solid-headed arrow: Solved-by
Parallelogram: Strategy
Strategy
Hollow-headed arrow: In context of
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Goal
Assumption
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Evidence
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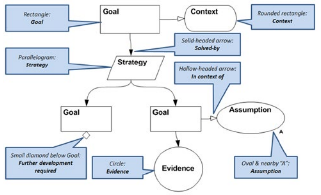
Implementation Assurance Case



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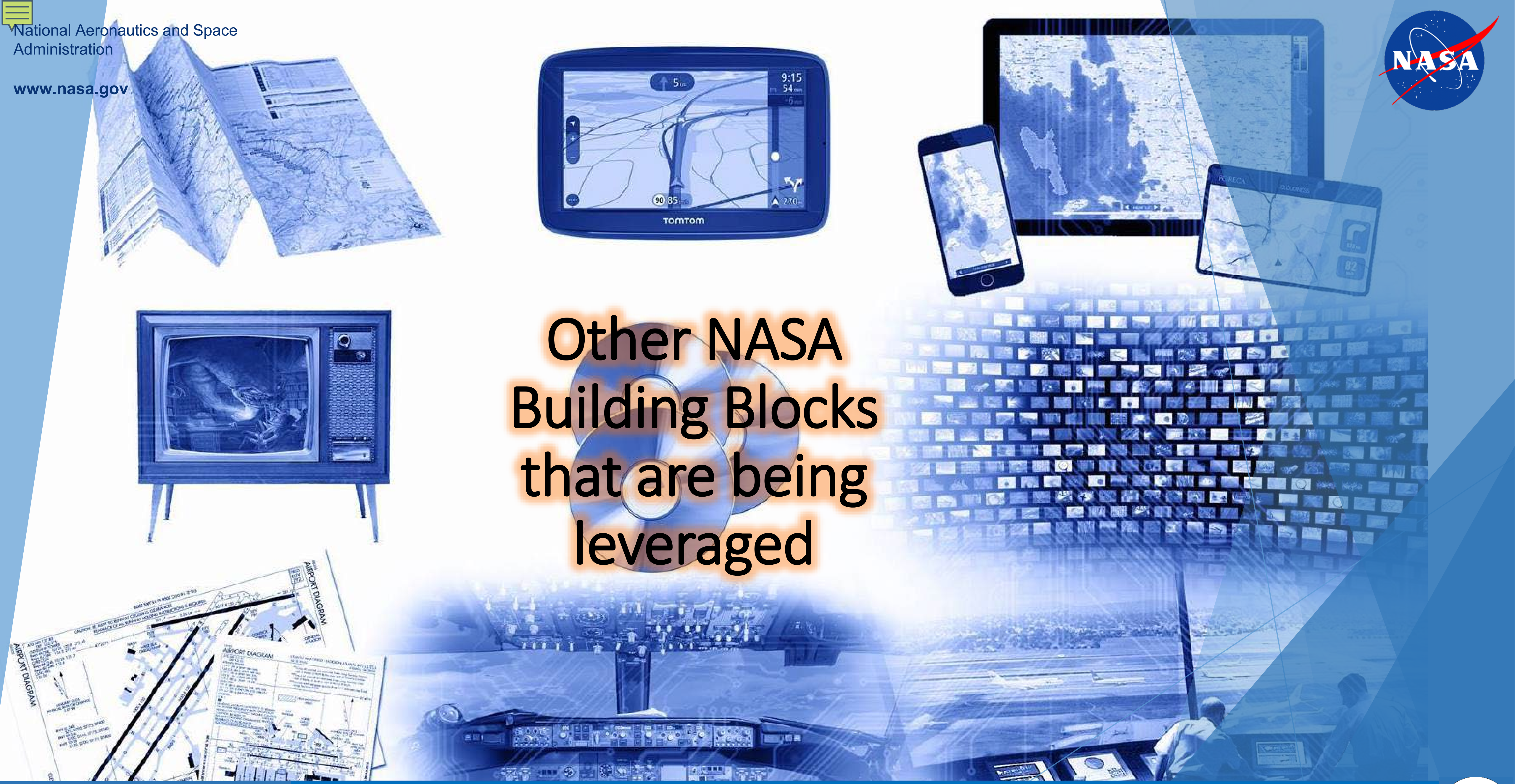
OPERATIONAL Assurance Case

Assurance Case Evolution

Traditionally, a Safety (Assurance) case is a static thing*, but it should be an active document *[framework]



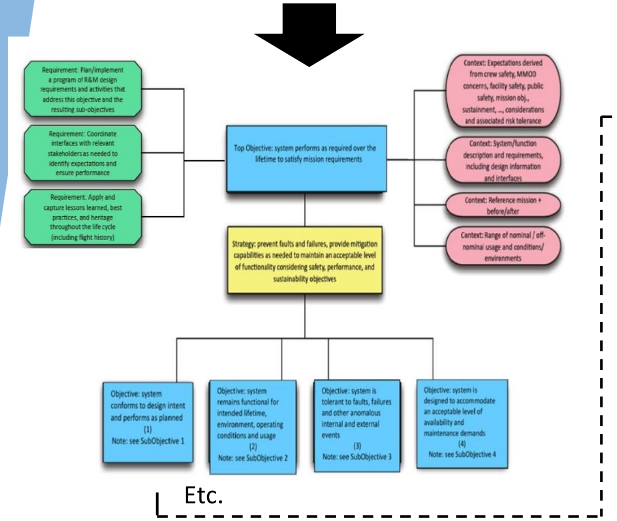
Other NASA Building Blocks that are being leveraged

R&M Objectives Hierarchy and Assurance Cases

An **Assurance Case** is an organized argument that a system is acceptable for its intended use with respect to specified concerns (such as safety, security, correctness)[1]

(Encompasses other terms: Safety/Dependability/Security Case)

NASA-STD-8729.1A provides a Reliability and Maintainability **GSN/Objectives Hierarchy** showing the top-level concerns while systematically providing more specifics that a project will need to address to assure reliability is designed and built into systems



Requirement: Plan/implement a program of R&M design requirements and activities that address this objective and the resulting sub-objectives

Requirement: Coordinate interfaces with relevant stakeholders as needed to identify expectations and ensure performance

Requirement: Apply and capture lessons learned, best practices, and heritage throughout the life cycle (including flight history)

Top Objective: system performs as required over the lifetime to satisfy mission requirements

Context: Expectations derived from crew safety, MMOD concerns, facility safety, public safety, mission obj., sustainment, ..., considerations and associated risk tolerance

Context: System/function description and requirements, including design information and interfaces

Context: Reference mission + before/after

Context: Range of nominal / off-nominal usage and conditions/ environments

Strategy: prevent faults and failures, provide mitigation capabilities as needed to maintain an acceptable level of functionality considering safety, performance, and sustainability objectives

Objective: system conforms to design intent and performs as planned (1) Note: see SubObjective 1

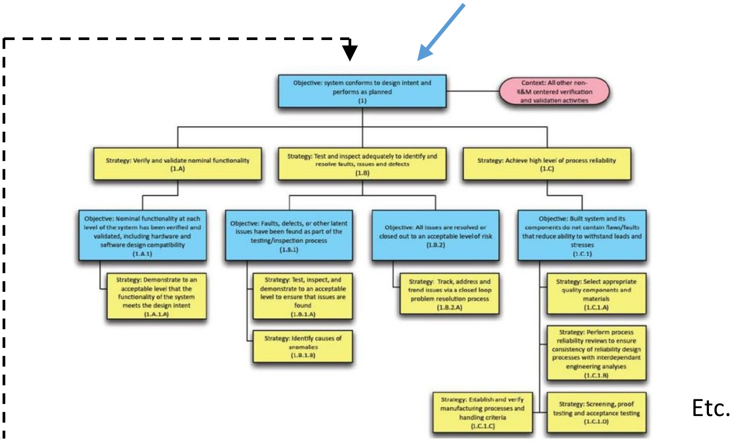
Objective: system remains functional for intended lifetime, environment, operating conditions and usage (2) Note: see SubObjective 2

Objective: system is tolerant to faults, failures and other anomalous internal and external events (3) Note: see SubObjective 3

Objective: system is designed to accommodate an acceptable level of availability and maintenance demands (4) Note: see SubObjective 4

Etc.

System conforms to design intent and performs as planned



Objective: system conforms to design intent and performs as planned (1)

Context: All other non-R&M centered verification and validation activities

Strategy: Verify and validate nominal functionality (1.A)

Strategy: Test and inspect adequately to identify and resolve faults, issues and defects (1.B)

Strategy: Achieve high level of process reliability (1.C)

Objective: Nominal functionality at each level of the system has been verified and validated, including hardware and software design compatibility (1.A.1)

Objective: Faults, defects, or other latent issues have been found as part of the testing/inspection process (1.B.1)

Objective: All issues are resolved or closed out to an acceptable level of risk (1.B.2)

Objective: Built system and its components do not contain flaws/faults that reduce ability to withstand loads and stresses (1.C.1)

Strategy: Demonstrate to an acceptable level that the functionality of the system meets the design intent (1.A.1.A)

Strategy: Test, inspect, and demonstrate to an acceptable level to ensure that issues are found (1.B.1.A)

Strategy: Identify causes of anomalies (1.B.1.B)

Strategy: Track, address and trend issues via a closed loop problem resolution process (1.B.2.A)

Strategy: Select appropriate quality components and materials (1.C.1.A)

Strategy: Perform process reliability reviews to ensure consistency of reliability design processes with interdependant engineering analyses (1.C.1.B)

Strategy: Establish and verify manufacturing processes and handling criteria (1.C.1.C)

Strategy: Screening, proof testing and acceptance testing (1.C.1.D)

Etc.

This hierarchy is a *starting point* for developing and/or reviewing an Assurance Case for a system's reliability

Other SMA/S&MS Objectives Hierarchy and Assurance Case Applications

Goal Structuring Notation in a Radiation Hardening Assurance Case for COTS-Based Spacecraft

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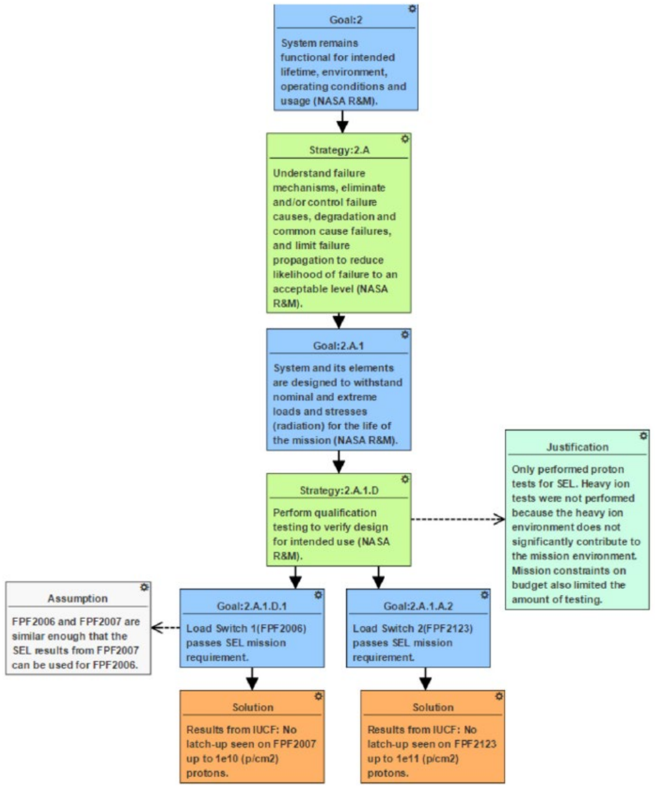


Goal:2
System remains functional for intended lifetime, environment, operating conditions and usage (NASA R&M).

Strategy:2.A
Understand failure mechanisms, eliminate and/or control failure causes, degradation and common cause failures, and limit failure propagation to reduce likelihood of failure to an acceptable level (NASA R&M).

Goal:2.A.1
System and its elements are designed to withstand nominal and extreme loads and stresses (radiation) for the life of the mission (NASA R&M).

Strategy:2.A.1.D
Perform qualification testing to verify design for intended use (NASA R&M).

Justification
Only performed proton tests for SEL. Heavy ion tests were not performed because the heavy ion environment does not significantly contribute to the mission environment. Mission constraints on budget also limited the amount of testing.

Assumption
FPF2006 and FPF2007 are similar enough that the SEL results from FPF2007 can be used for FPF2006.

Goal:2.A.1.D.1
Load Switch 1(FPF2006) passes SEL mission requirement.

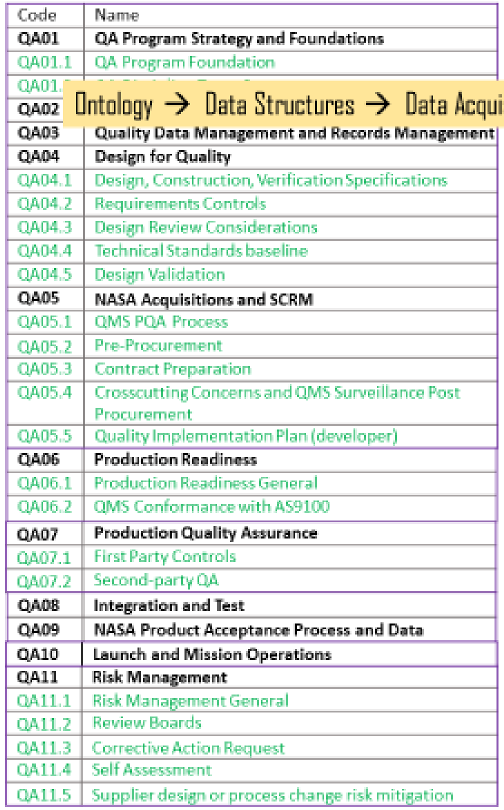
Goal:2.A.1.A.2
Load Switch 2(FPF2123) passes SEL mission requirement.

Solution
Results from IUCF: No latch-up seen on FPF2007 up to 1e10 (p/cm2) protons.

Solution
Results from IUCF: No latch-up seen on FPF2123 up to 1e11 (p/cm2) protons.

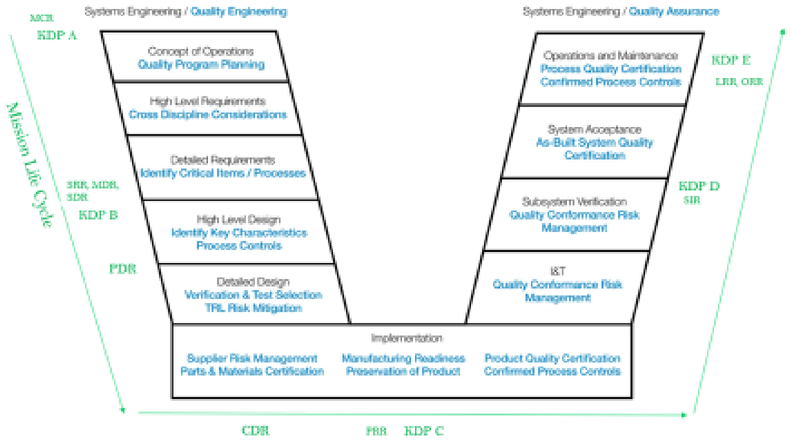
Hardware Quality Assurance

Ontology → Data Structures → Data Acquisition → Data Sharing → Populating Models → Understanding the State of the System



Code	Name
QA01	QA Program Strategy and Foundations
QA01.1	QA Program Foundation
QA01.	
QA02	
QA03	Quality Data Management and Records Management
QA04	Design for Quality
QA04.1	Design, Construction, Verification Specifications
QA04.2	Requirements Controls
QA04.3	Design Review Considerations
QA04.4	Technical Standards baseline
QA04.5	Design Validation
QA05	NASA Acquisitions and SCRM
QA05.1	QMS PQA Process
QA05.2	Pre-Procurement
QA05.3	Contract Preparation
QA05.4	Crosscutting Concerns and QMS Surveillance Post Procurement
QA05.5	Quality Implementation Plan (developer)
QA06	Production Readiness
QA06.1	Production Readiness General
QA06.2	QMS Conformance with AS9100
QA07	Production Quality Assurance
QA07.1	First Party Controls
QA07.2	Second-party QA
QA08	Integration and Test
QA09	NASA Product Acceptance Process and Data
QA10	Launch and Mission Operations
QA11	Risk Management
QA11.1	Risk Management General
QA11.2	Review Boards
QA11.3	Corrective Action Request
QA11.4	Self Assessment
QA11.5	Supplier design or process change risk mitigation

Etc.

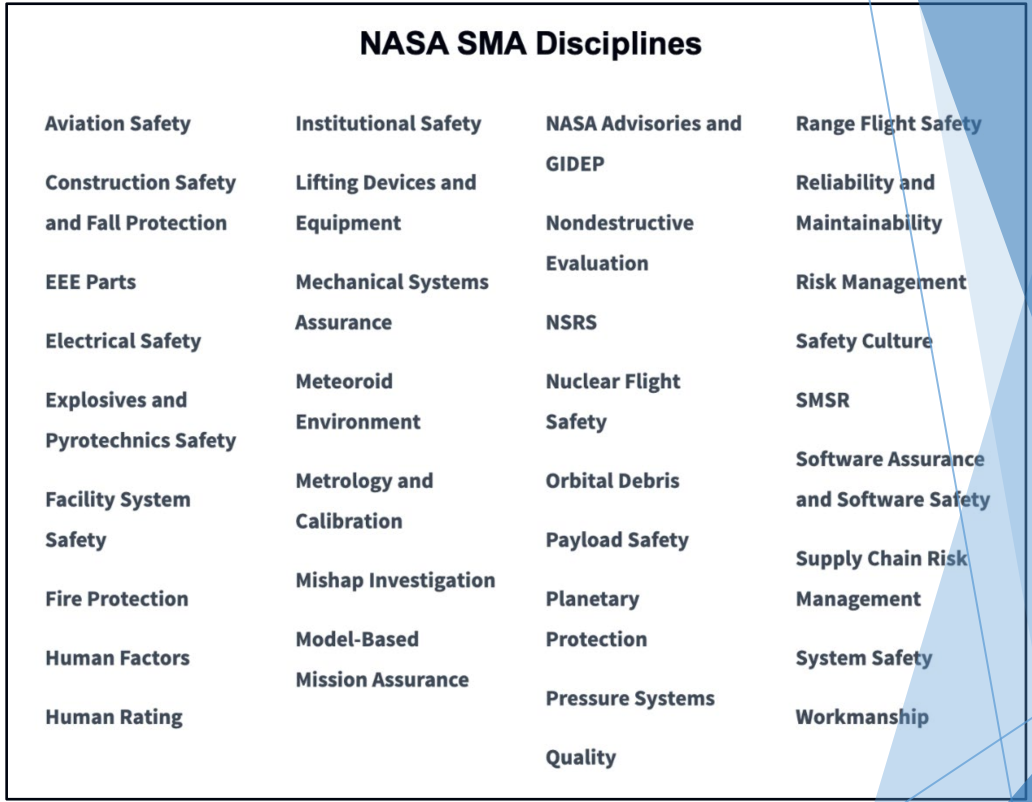

Systems Engineering / Quality Engineering
Systems Engineering / Quality Assurance
MCR
KDP A
Mission Life Cycle
Concept of Operations
Quality Program Planning
High Level Requirements
Cross Discipline Considerations
Detailed Requirements
Identify Critical Items / Processes
SRR, MDR, SDR
KDP B
High Level Design
Identify Key Characteristics
Process Controls
PDR
Detailed Design
Verification & Test Selection
TRL Risk Mitigation
Implementation
Supplier Risk Management
Parts & Materials Certification
Manufacturing Readiness
Preservation of Product
Product Quality Certification
Confirmed Process Controls
CDR
PRR
KDP C
I&T
Quality Conformance Risk Management
Subsystem Verification
Quality Conformance Risk Management
KDP D
SIR
System Acceptance
As-Built System Quality Certification
Operations and Maintenance
Process Quality Certification
Confirmed Process Controls
KDP E
LRR, ORR

NPR 8735.2C QA Policy Ontology *(draft)*:

- ~400 Limbs, branches, and leaves; 11 "limbs" are main QA process elements
- Designed for associating data: requirements, results, records
- NASA mission lifecycle order

Extending Objectives Hierarchies not only to other SMA Discipline Areas, but to our Aligned Set of NPD 8700 Top Objectives

- SMA/S&MS activities have traditionally been planned and addressed via individual SMA Disciplines
- Makes these SMA/S&MS activities vulnerable to being Siloed.
- Need a Framework to begin Integrating various Discipline activities/Objective Hierarchies together around a broader SMA/S&MS Objectives Hierarchy and Assurance Case Framework.



NASA SMA Disciplines

Aviation Safety

Construction Safety and Fall Protection

EEE Parts

Electrical Safety

Explosives and Pyrotechnics Safety

Facility System Safety

Fire Protection

Human Factors

Human Rating

Institutional Safety

Lifting Devices and Equipment

Mechanical Systems Assurance

Meteoroid Environment

Metrology and Calibration

Mishap Investigation

Model-Based Mission Assurance

NASA Advisories and GIDEP

Nondestructive Evaluation

NSRS

Nuclear Flight Safety

Orbital Debris

Payload Safety

Planetary Protection

Pressure Systems

Quality

Range Flight Safety

Reliability and Maintainability

Risk Management

Safety Culture

SMSR

Software Assurance and Software Safety

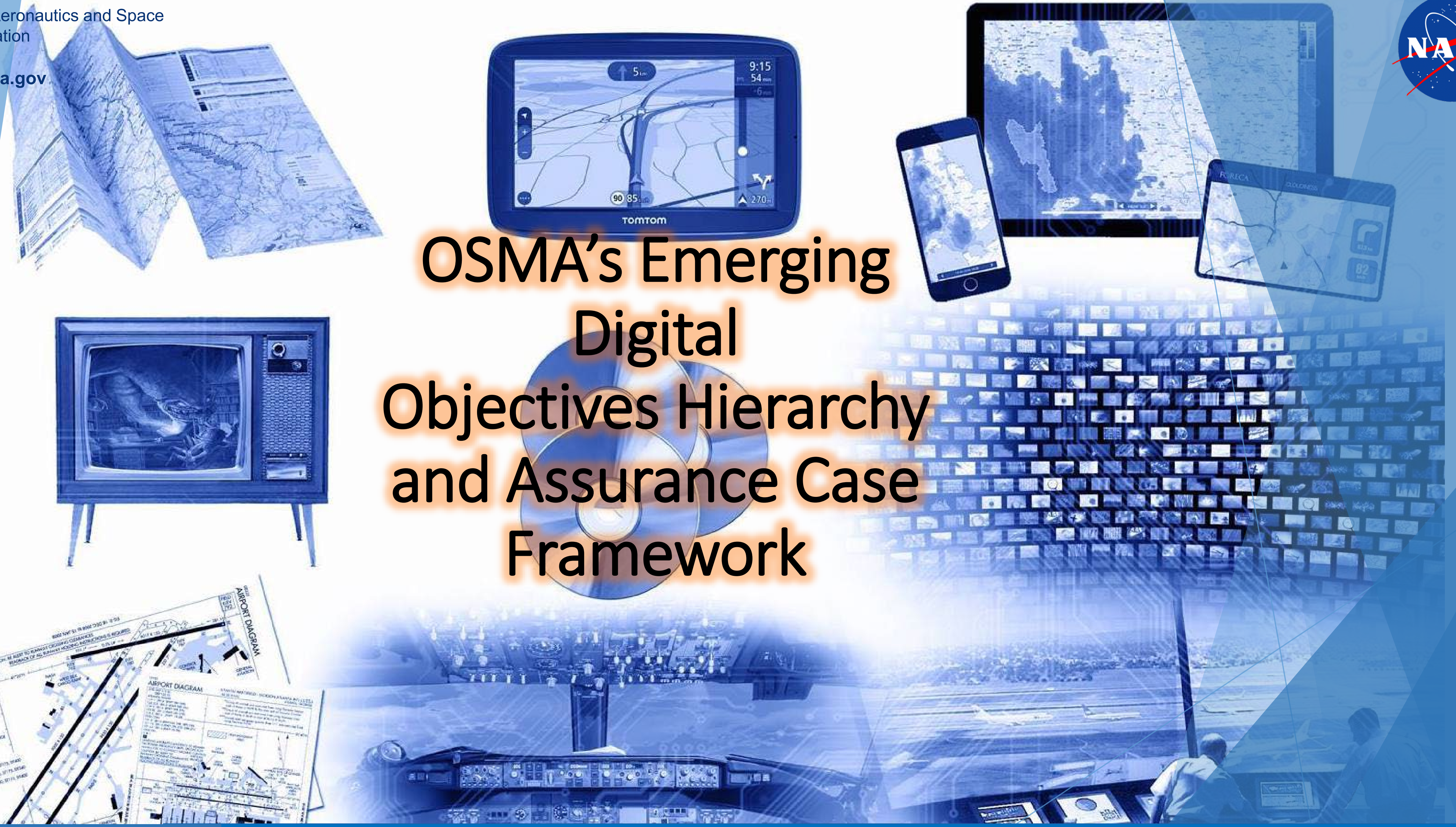
Supply Chain Risk Management

System Safety

Workmanship

National Aeronautics and Space Administration

www.nasa.gov



OSMA's Emerging Digital Objectives Hierarchy and Assurance Case Framework

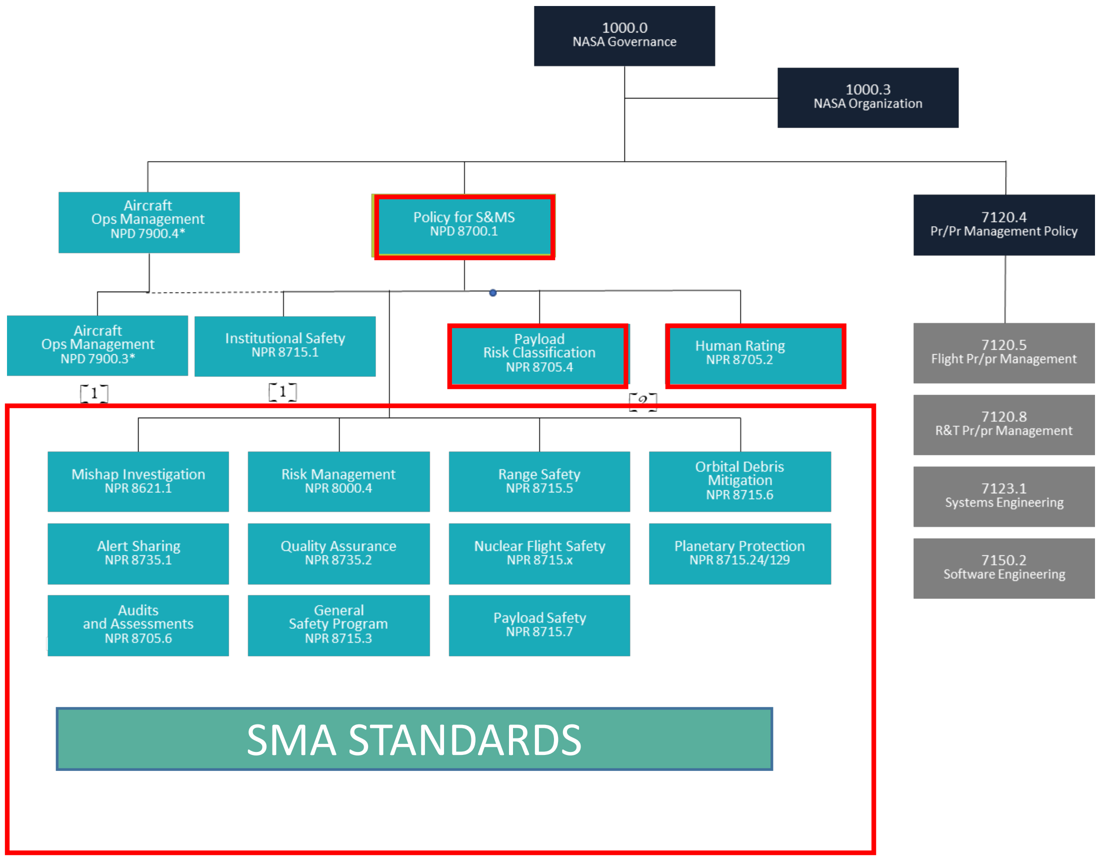
OSMA
OFFICE OF SAFETY & MISSION ASSURANCE

Mission Assurance Standards and Capabilities Division
OSMA HQ-GD000

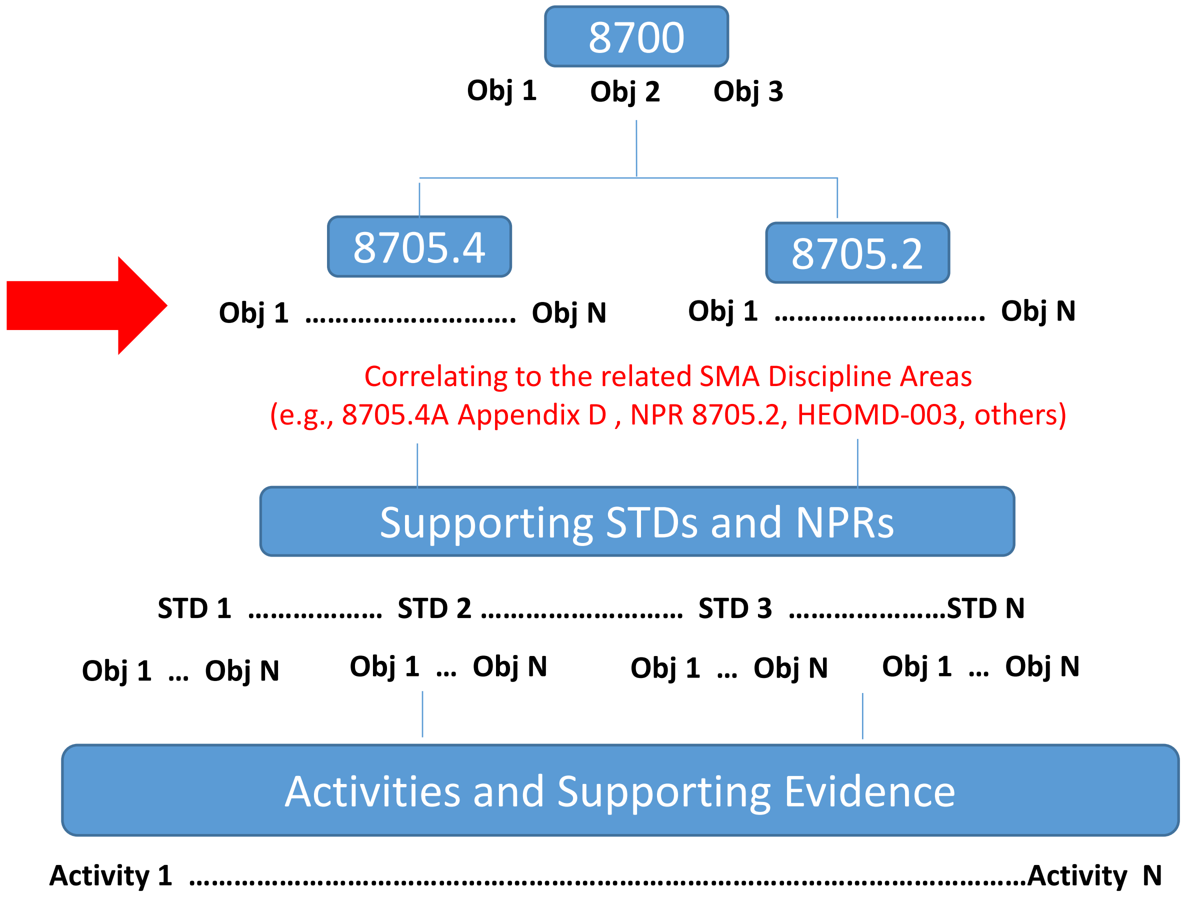
Policy Enabled - Integrated Objectives Hierarchy

On-Ramp for SMA Interoperability

SMA’s Policies and STDs



SMA’s Objectives Hierarchy


8700
Obj 1
Obj 2
Obj 3
8705.4
8705.2
Obj 1 ………………………. Obj N
Obj 1 ………………………. Obj N
Correlating to the related SMA Discipline Areas
(e.g., 8705.4A Appendix D , NPR 8705.2, HEOMD-003, others)
Supporting STDs and NPRs
STD 1 ……………… STD 2 ……………………… STD 3 ………………..STD N
Obj 1 … Obj N
Obj 1 … Obj N
Obj 1 … Obj N
Obj 1 … Obj N
Activities and Supporting Evidence
Activity 1 ………………………………………………………………………………Activity N

Automated Project Plan Generator (APPG) Engine

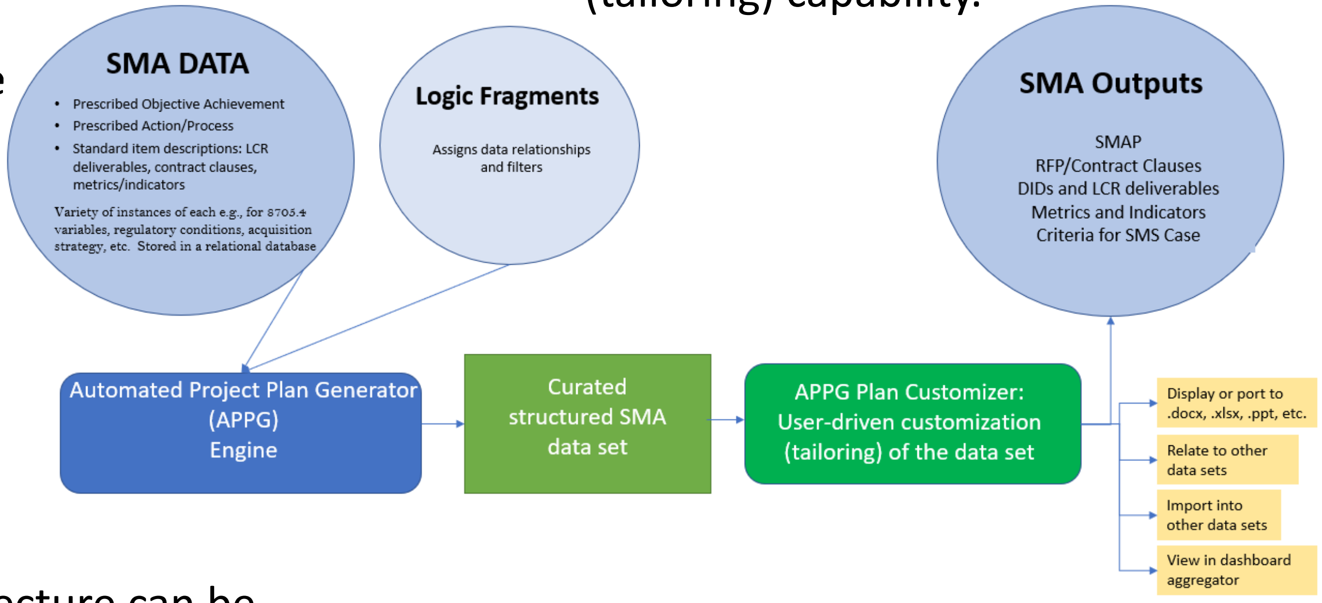
Repeatable, SME-curated, OSMA-endorsed recommendations on demand

OJT: Learn as tool is used

Project experts have direct access to editing (tailoring) capability.

Authoritative Source traceable to OSMA Policy

Project personnel only spend time tailoring, not building content from the ground up.



SMA DATA

- Prescribed Objective Achievement
- Prescribed Action/Process
- Standard item descriptions: LCR deliverables, contract clauses, metrics/indicators

Variety of instances of each e.g., for 8705.4 variables, regulatory conditions, acquisition strategy, etc. Stored in a relational database

Logic Fragments

Assigns data relationships and filters

Automated Project Plan Generator (APPG) Engine

Curated structured SMA data set

APPG Plan Customizer: User-driven customization (tailoring) of the data set

SMA Outputs

SMAP
RFP/Contract Clauses
DIDs and LCR deliverables
Metrics and Indicators
Criteria for SMS Case

Display or port to .docx, .xlsx, .ppt, etc.

Relate to other data sets

Import into other data sets

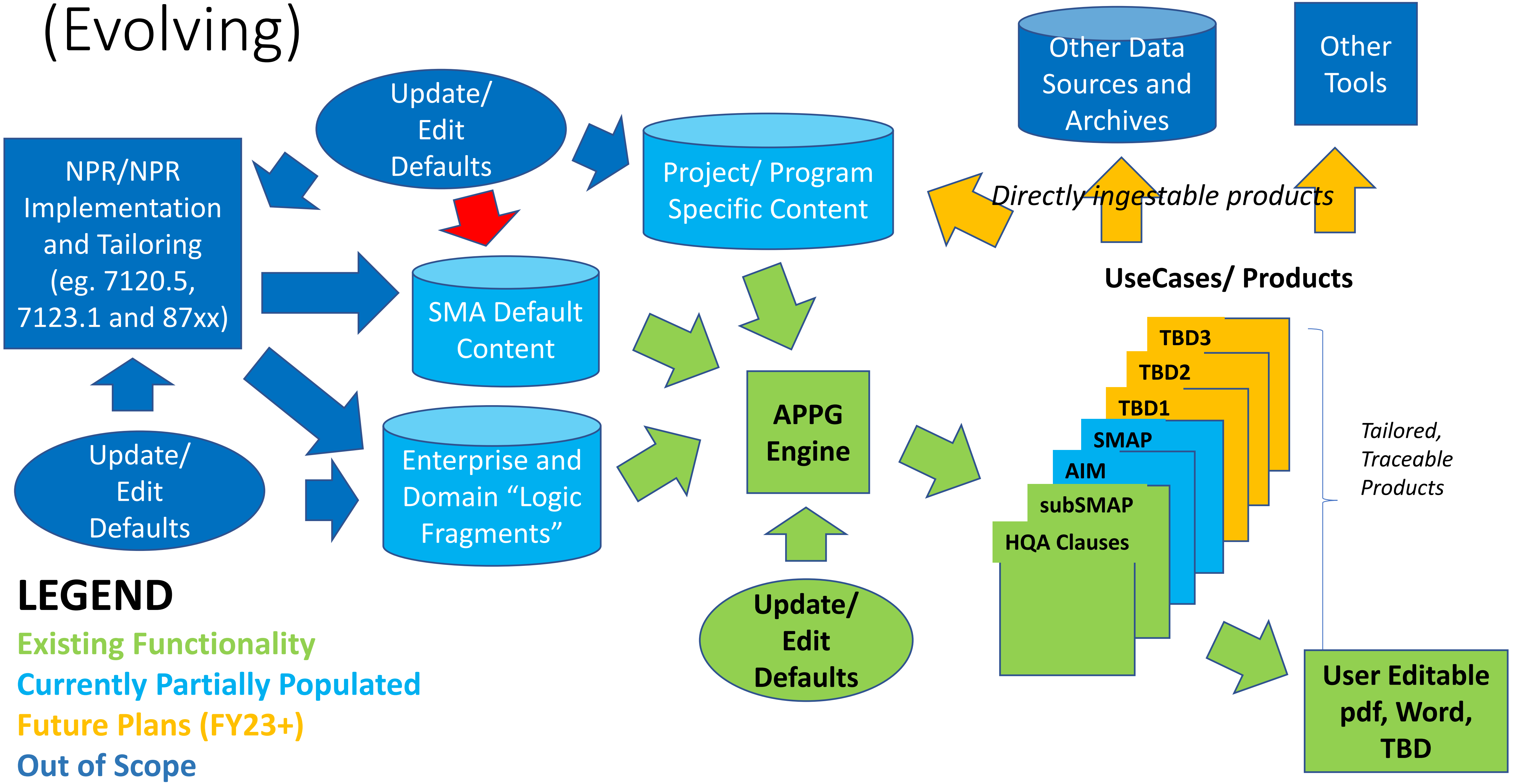
View in dashboard aggregator

Back-end analysis of data sets for improvements, trends, risk awareness

Data architecture can be expanded over time: attach templates, related policy statement*, etc.

Content held as a data set. Can be related to other data sets and support analytics.

APPG in a larger Context (Evolving)



Update/ Edit Defaults

NPR/NPR Implementation and Tailoring (eg. 7120.5, 7123.1 and 87xx)

Update/ Edit Defaults

SMA Default Content

Enterprise and Domain "Logic Fragments"

Project/ Program Specific Content

APPG Engine

Update/ Edit Defaults

Other Data Sources and Archives

Other Tools

Directly ingestable products

UseCases/ Products

TBD3

TBD2

TBD1

SMAP

AIM

subSMAP

HQA Clauses

Tailored, Traceable Products

User Editable pdf, Word, TBD

LEGEND

Existing Functionality

Currently Partially Populated

Future Plans (FY23+)

Out of Scope

Assurance Case Framework: Objectives Driven Requirements, Accepted STDs, and Evidence

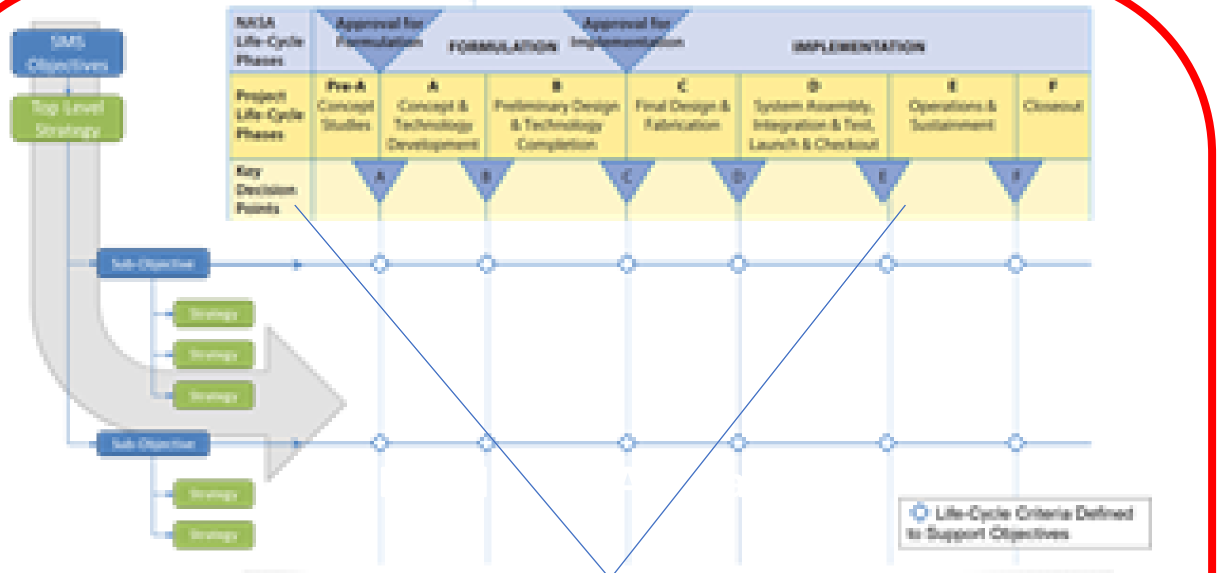
AIM and SMAP – KEY Elements for Planning and Execution

NPD 8700
Establish Top Level Objectives

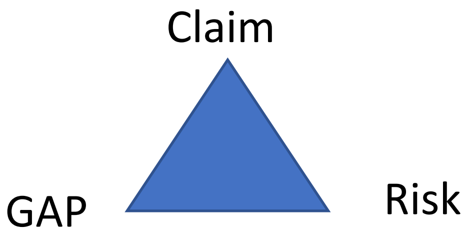
NPR 8705
Establish Mid Level Objectives (AIM, SMAP)
(Mission Driven Use of Accepted STDs)

Sub NPRs / STDs
Establish Lower Level Objectives and Evidence Reqts

Formulation and Planning
Crewed – 7120.5, 7123.2, and 8705.2
Robotic – 7120.5, 7123.2, and 8705.4


SMS Objectives
Top Level Strategy
Sub-Objective
Strategy
Strategy
Strategy
Sub-Objective
Strategy
Strategy
NASA Life-Cycle Phases
Approval for Formulation
FORMULATION
Approval for Implementation
IMPLEMENTATION
Project Life-Cycle Phases
Pre-A Concept Studies
A Concept & Technology Development
B Preliminary Design & Technology Completion
C Final Design & Fabrication
D System Assembly, Integration & Test, Launch & Checkout
E Operations & Sustainment
F Closeout
Key Decision Points
Life-Cycle Criteria Defined to Support Objectives

Architecting: Establish Assurance Case Framework over the entire lifecycle
(Formulation/Planning through Launch/Operations)



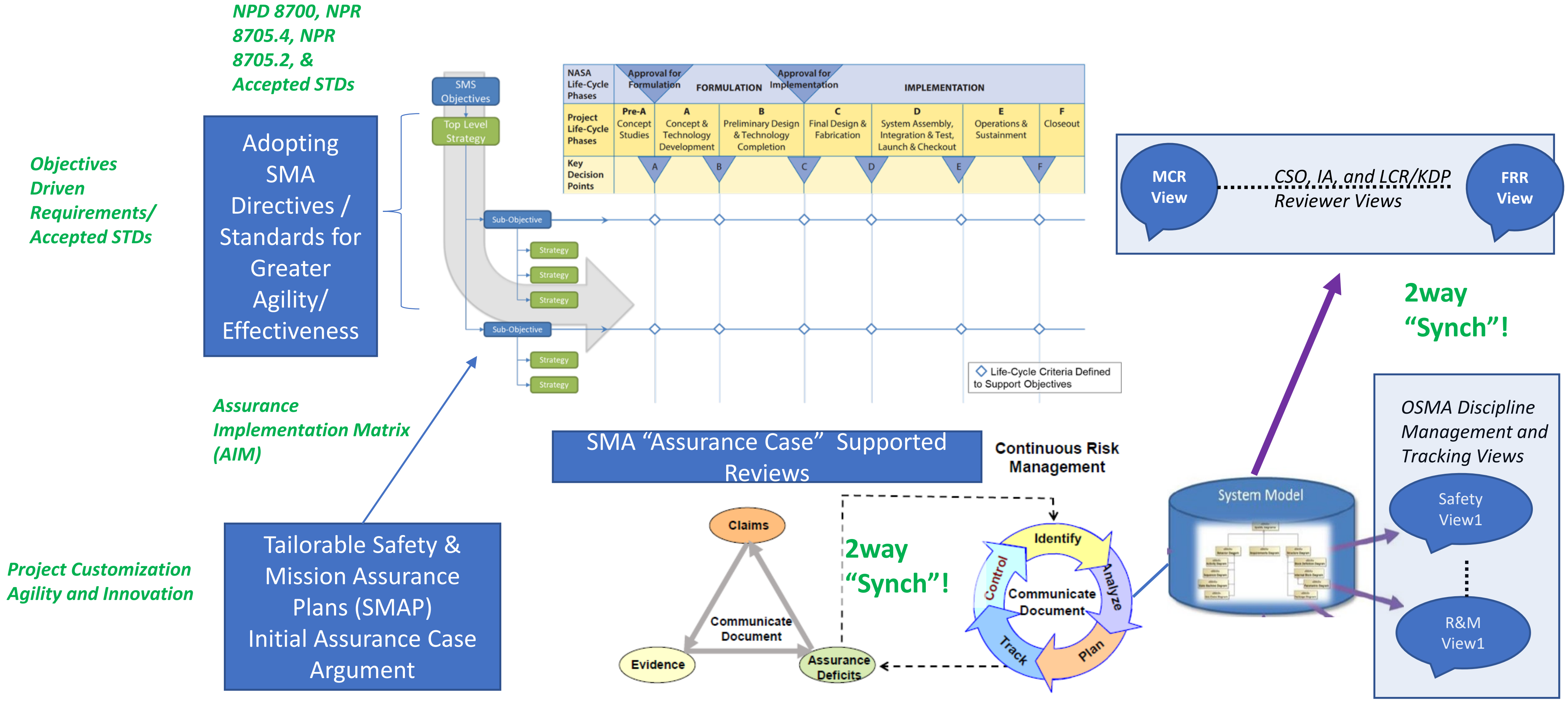
V&V Top Level Objectives
(vs NPD 8700)

V&V Mid Level Objectives
vs Project AIM/SMAP
(Tailored Standards Application)

Lower-level Integration and V&V
(Evidence Claims, Issues, Risks)

SMA’s Digital Future

Digital Twin enabled Objectives Hierarchy/SMS Assurance Case Framework with Machine-Assisted Planning, Machine-Assisted Assurance Case Development, and Machine-Assisted Reviews



NPD 8700, NPR 8705.4, NPR 8705.2, & Accepted STDs

Objectives Driven Requirements/ Accepted STDs

Adopting SMA Directives / Standards for Greater Agility/ Effectiveness

Assurance Implementation Matrix (AIM)

Project Customization Agility and Innovation

Tailorable Safety & Mission Assurance Plans (SMAP) Initial Assurance Case Argument

NASA Life-Cycle Phases	Approval for Formulation	FORMULATION		Approval for Implementation	IMPLEMENTATION		
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Key Decision Points	A	B	C	D	E	F	

◇ Life-Cycle Criteria Defined to Support Objectives

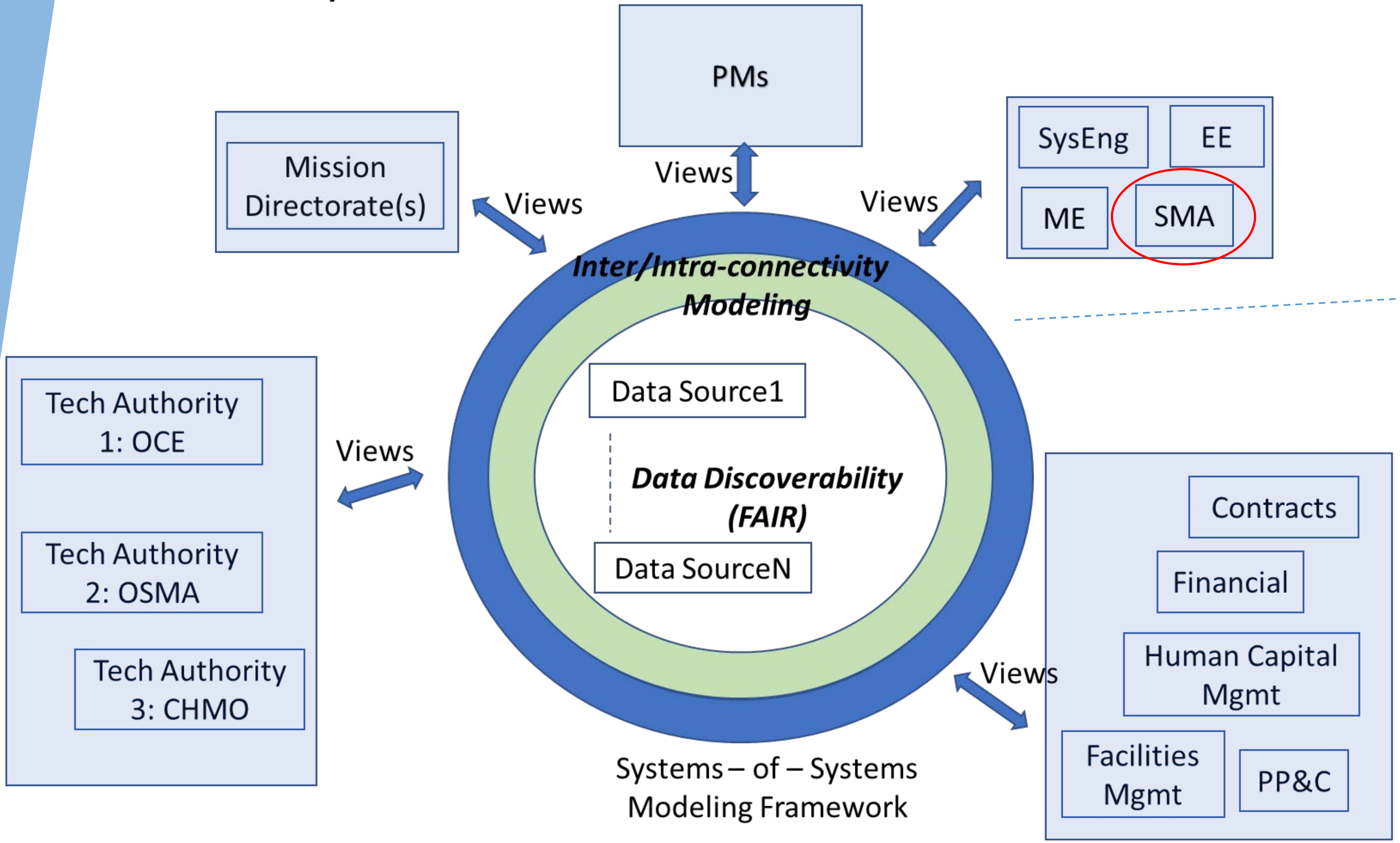
SMA “Assurance Case” Supported Reviews

Continuous Risk Management

Back-Up

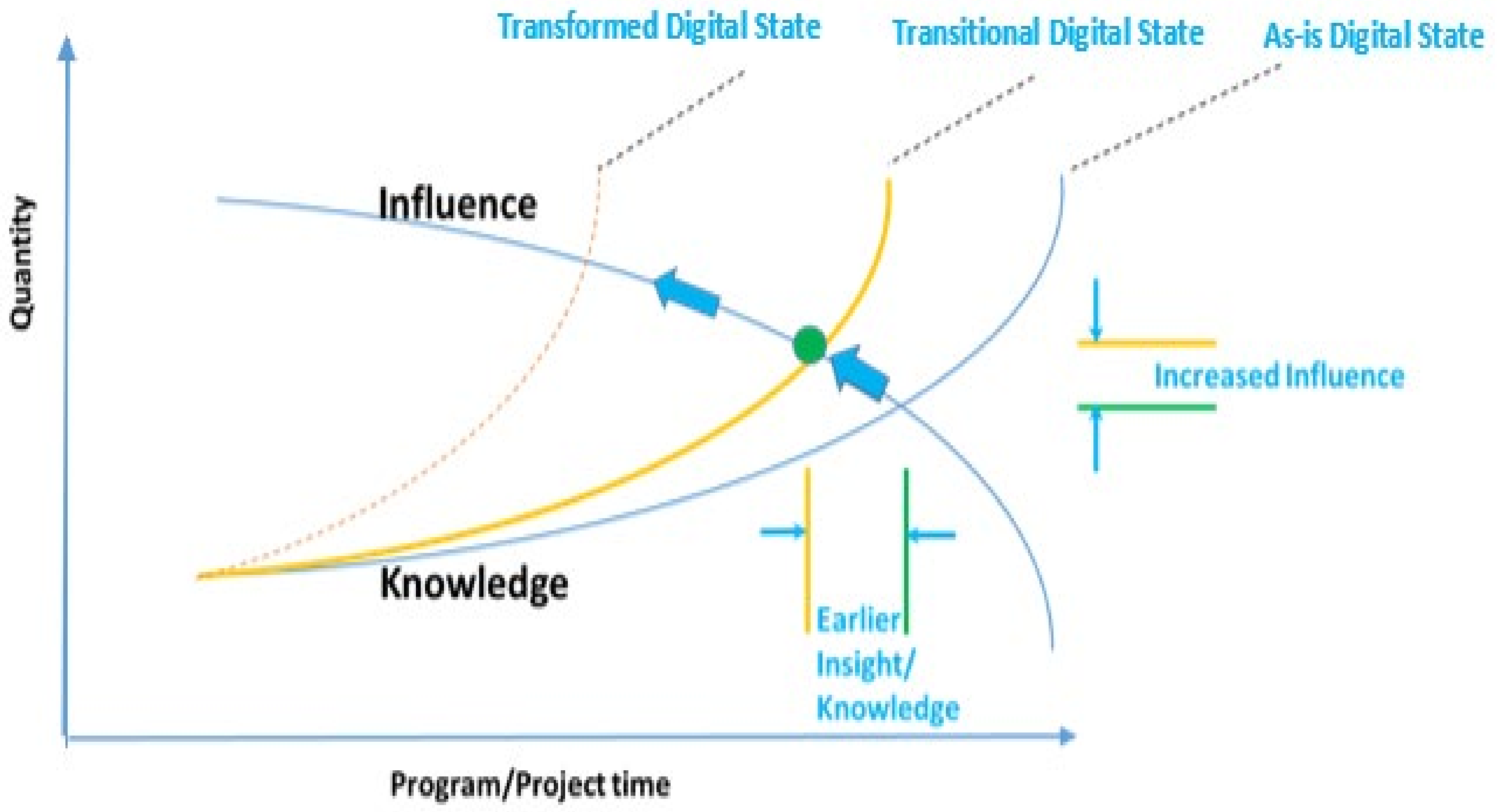
Interoperability

Everyone has a Seat at the TABLE

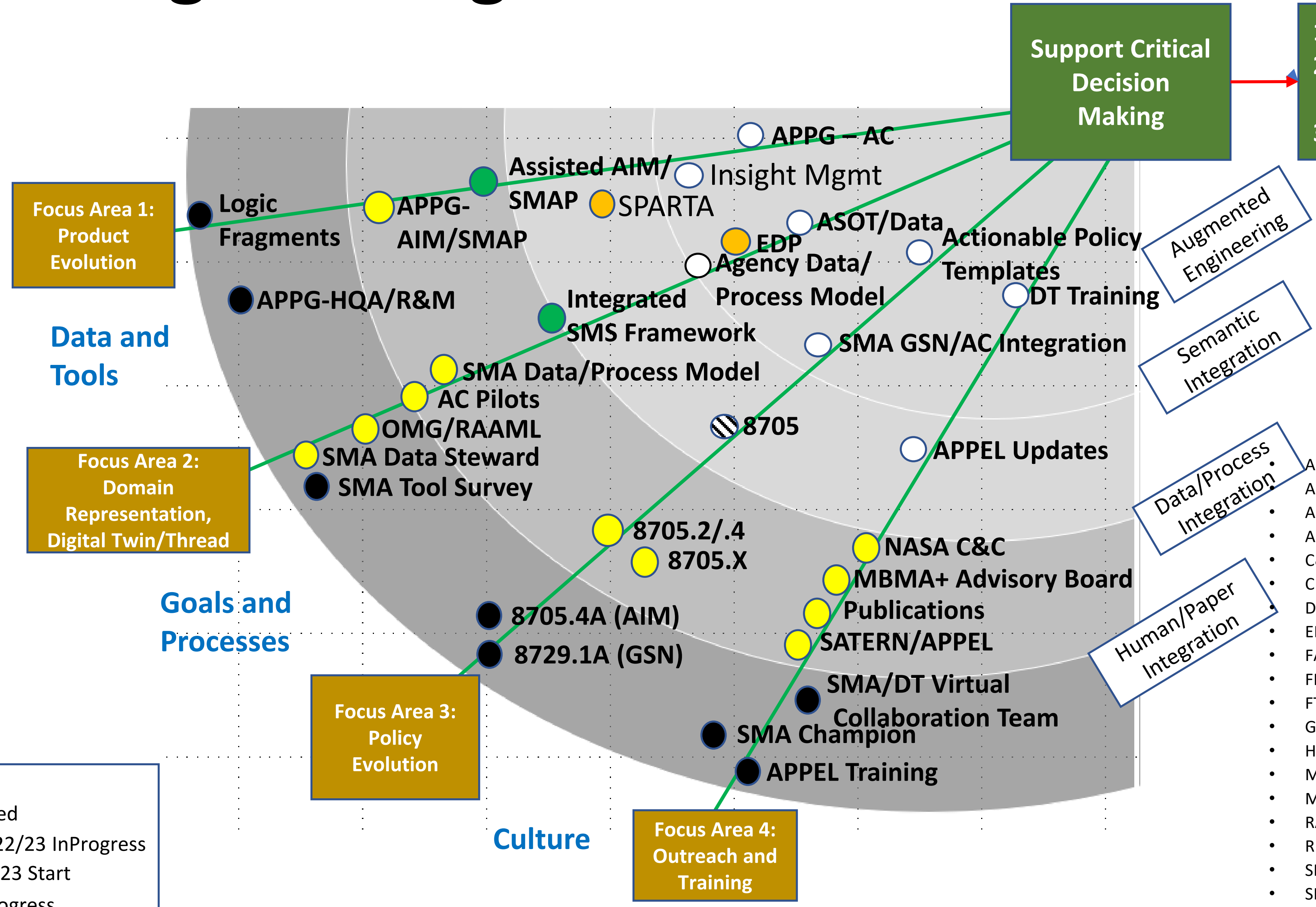


Authoritative Source of Truth

Knowledge vs Influence Curve SMA Impact on “Critical Decision Making”



Evolving SMA Digital Transformation Roadmap



1. Increased Decision Velocity,
2. Risk Integration and Robust Contextualization
3. Maximize Efficiency

LEGEND

- ● Completed
- ● SMA-2022/23 InProgress
- ● SMA- 2023 Start
- ● DT-In Progress
- ○ Research Needed

Acronyms

- AC = Assurance/Safety Case
- AIM = Assurance Implementation matrix
- ANASWA=R&M Logic Fragment Engine
- APPG = Automated Program Plan Generator
- C&C = NSC Content and Collaboration Project
- CRM = Continuous Risk Management
- DT = Digital Transformation
- EDP – Enterprise Data Platform
- FAIR = Findable, Assessable, Interoperable and Reusable
- FMEA=Failure Modes Effects Analysis
- FTA=Fault Tree Analysis
- GSN = Goal Structuring Notation
- HQA = Hardware Quality Assurance
- MB = Model-Based
- MBMA+ = Model-Based Safety and Mission Assurance
- RAAML = Risk Assessment and Modeling Language
- RIDM = Risk Informed Decision Making
- SMA = Safety and Mission Assurance
- SMAP = SMA Plan
- SPARTA=Smart Project and Reviews with Transformative Analytics (SPARTA)

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SMA Transformational Activities and Emerging Benefits