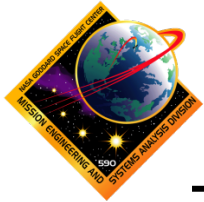# Systems Engineering Standards in Action
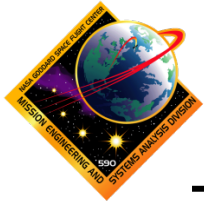
Systems Engineering Seminar
November 8, 2012
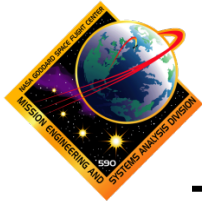
Cynthia Firman
Code 599/504

Agenda

- **Requirements**
- **Introduction to NPR 7123.1A/GPR 7123.1A**
- **Planning**
- **Application of Standards to Projects**
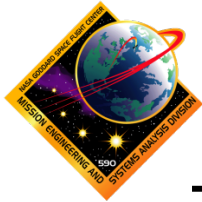- **Examples**

Requirements

Requirements and Products

- Imagine going to a car dealership and telling them you want a great car and gave no other "requirements", put a check on the table and walked off for lunch to take delivery when you return.

  - Which car would you be driving off the lot when you returned?

- Experience has shown that requirements become important at delivery time.

- Moral of this story: Take the time (and write them down) before the delivery to make sure you get what you expect!
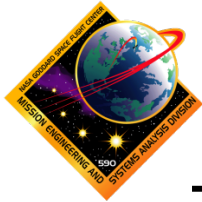
Requirements? We don't need requirements!
Let's cut some metal!

- **What is a Requirement and why do we write them?**
    - ✓ **Easily detectable: A requirement statement contains a "shall"**
    - ✓ **Creates agreements for the "product"**
    - ✓ **Conveys expectations to "Providers" and "Practitioners"**
    - ✓ **To ensure they are being implemented, compliance must be demonstrated along the way (through plans, tracking, allocation, verification, sign-off) to mark progress in meeting them**

- **Why are Requirements Important?**
    - ✓ **"Stakeholders" want to make sure the "product" delivered meets their needs, goals and objectives (NGO's)**
    - ✓ **Requirements ensure the objectives are communicated in a tangible, clear manner at every level of a project**
    - ✓ **Taking the time to develop requirements early in a project lifecycle helps ensure the "product" delivered meets expectations and creates a more efficient lifecycle (decomposing, building, testing, verification and the final delivery) – lots of studies show this!!!**

> - **Without requirements, you can't contain cost**
> - **Without requirements, you can't ensure you get what you are paying for**
> - **Without requirements, you don't know what will be delivered**

Requirements are Everywhere!

➢ **Ever Notice all the Requirements?**

- **Contracts (are Requirements)**
- **Statements of Work (SOWs) (are Requirements)**
- **Standards (are Requirements)**
- **Procedural Requirements (NASA Procedural Requirements**
  – NPR, Goddard Procedural Requirements - GPR)
- **Technical Requirements**
- **Safety Requirements**
- **Agency Requirements**
- **Procurement Requirements**
- **CSR Requirements**
- **Quality Requirements**
- **Environmental Verification Requirements**
- **Orbital Debris Requirements**
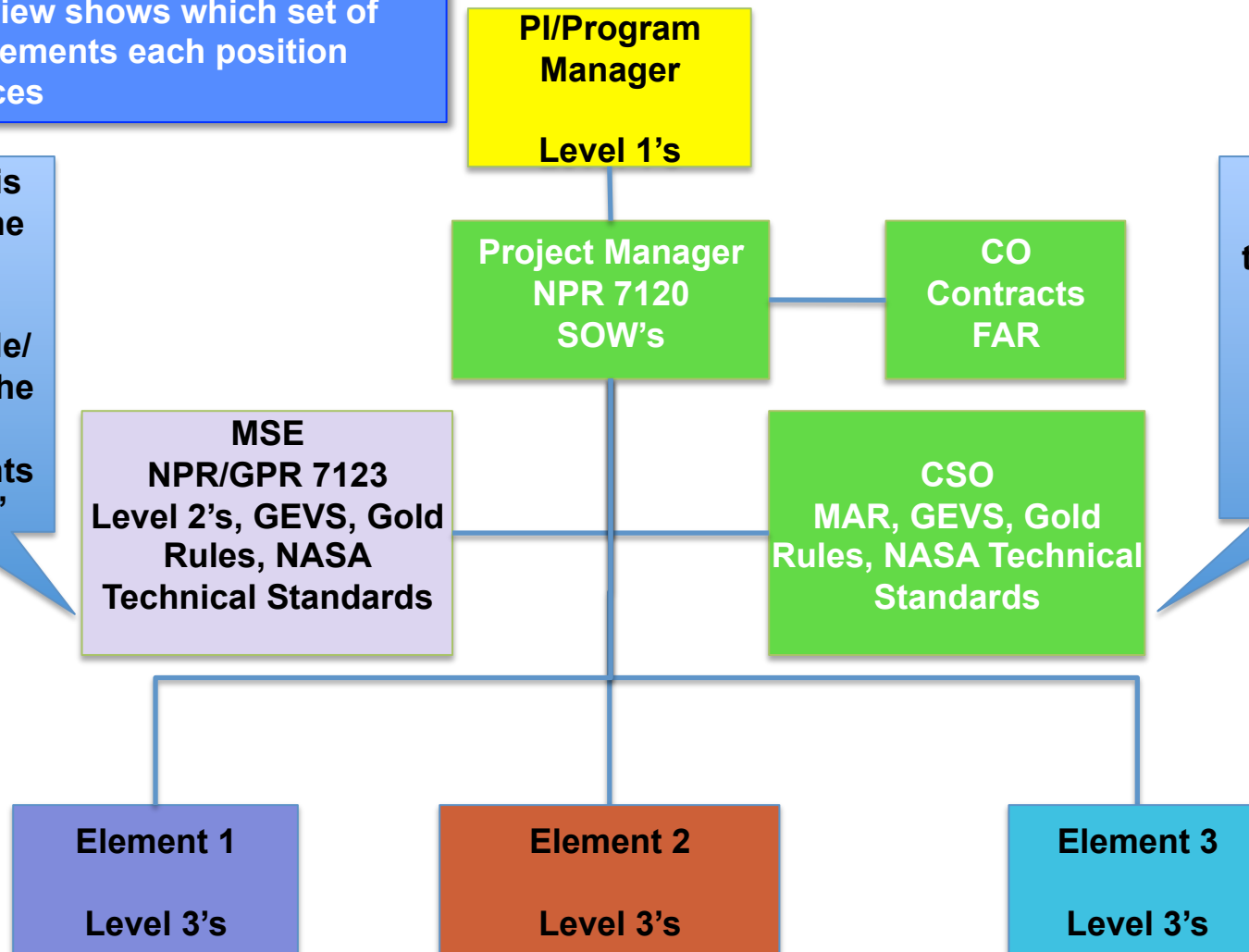- **Software Engineering Requirements**
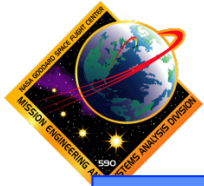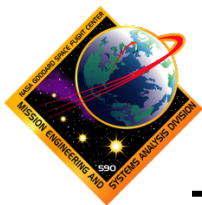
Requirements Based Project View

- Requirements Directly Map to the Organization Chart
- This view shows which set of requirements each position enforces

PI/Program Manager

Level 1's

The MSE is typically the TA for Mission Success. He/she owns the technical requirements "lockbox"

Project Manager
NPR 7120
SOW's

CO
Contracts
FAR

The CSO is typically the TA for S&MA. He/she owns the MAR "lockbox"

MSE
NPR/GPR 7123
Level 2's, GEVS, Gold Rules, NASA Technical Standards

CSO
MAR, GEVS, Gold Rules, NASA Technical Standards

Element 1

Level 3's

Element 2

Level 3's

Element 3

Level 3's

Requirements Flow Down
(Products Flow Up)

Level 1's

Project Documents

Parent

Allocation

Agree ments

SOW's

Project Plan

Level 2's

MAR

Parent

Allocation

Allocation

Level 3's
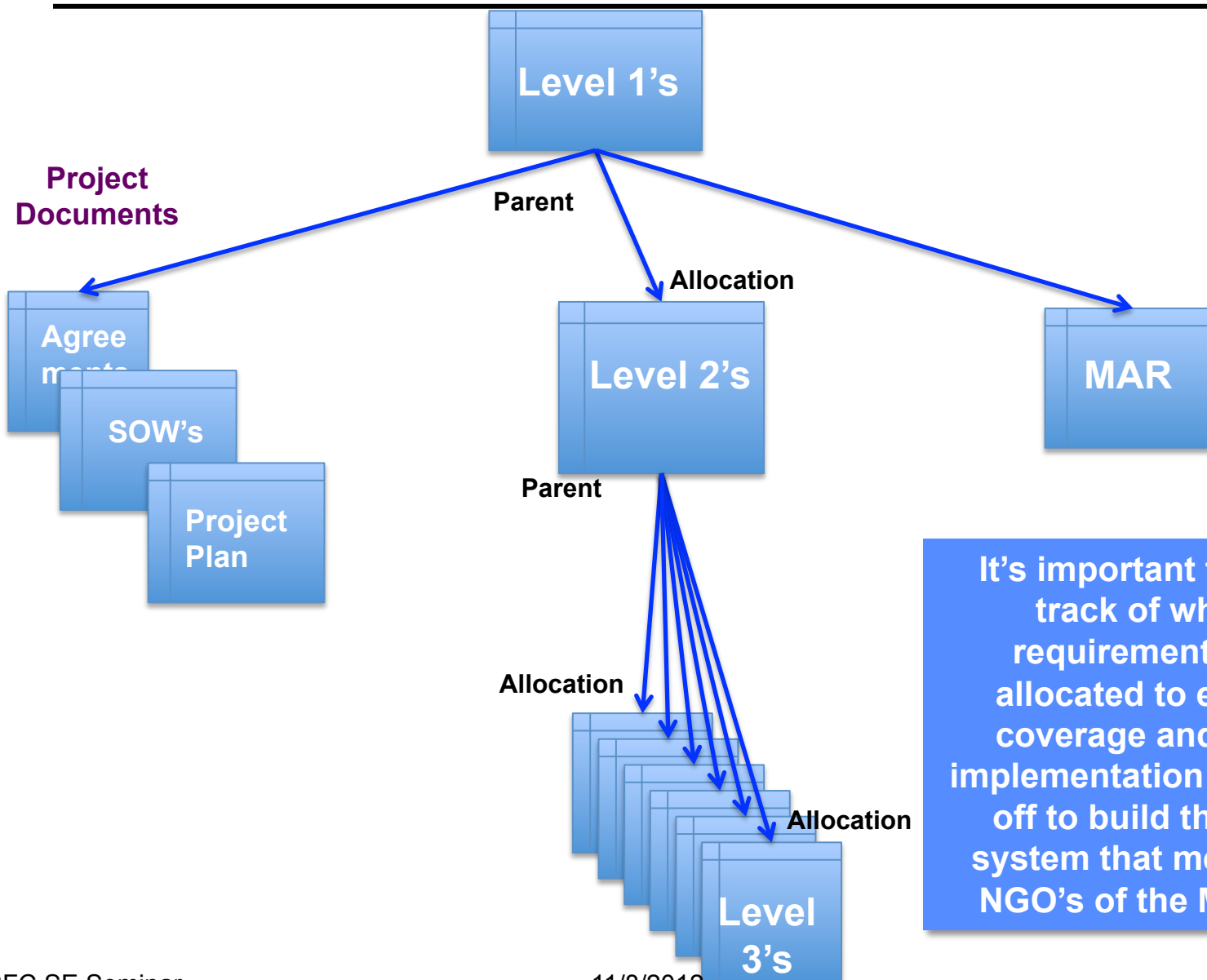
It's important to keep track of where requirements are allocated to ensure coverage and track implementation and sign off to build the final system that meets the NGO's of the Mission

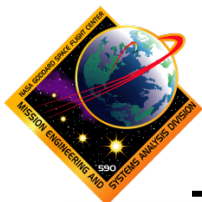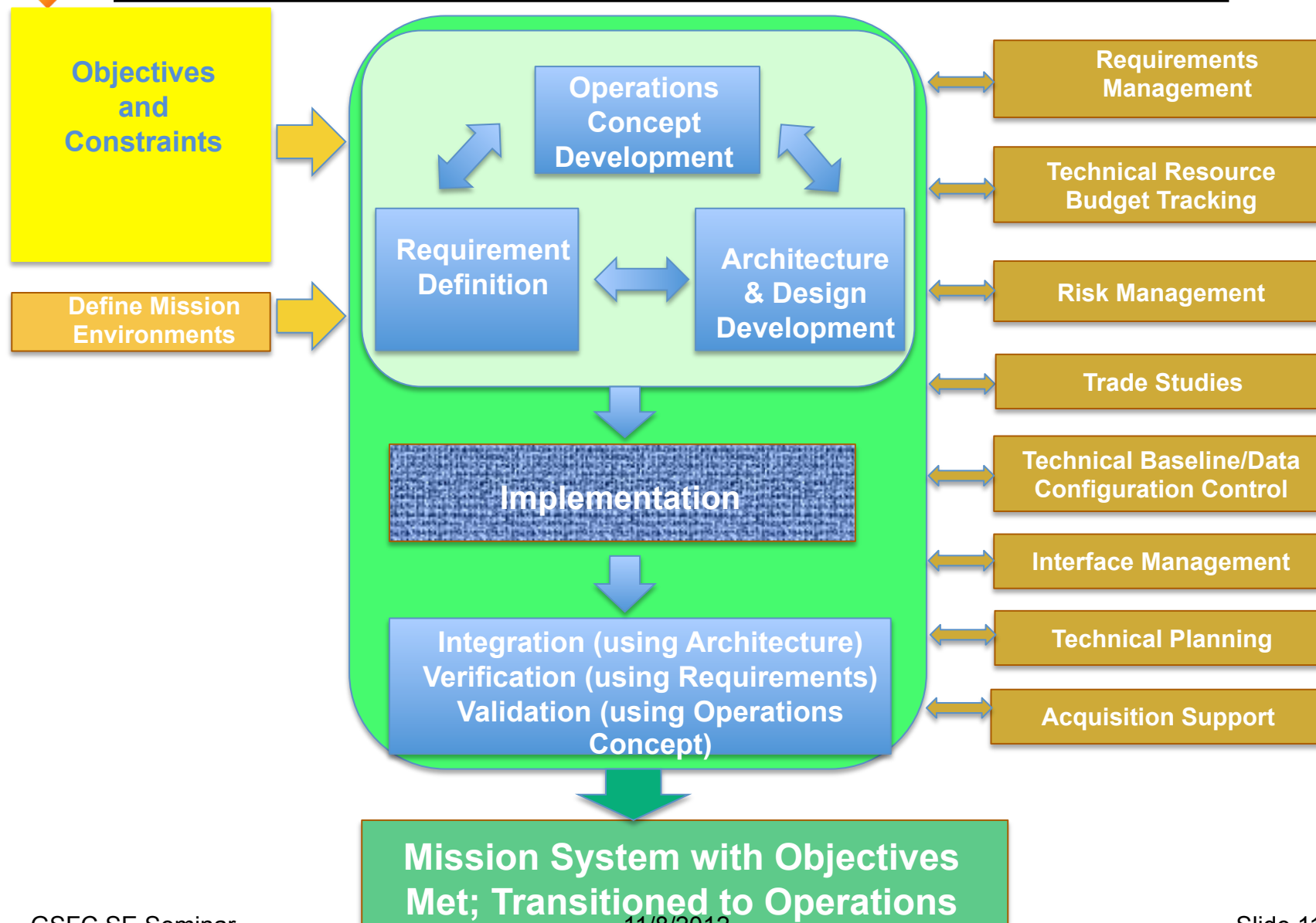# Systems Engineering Standards
(are Requirements)

NPR 7123, GPR 7123 and the GOLD Rules

- **NPR 7123.1A**: NASA Procedural Requirements for Systems Engineering
    - **Compliance is Mandatory for every NASA Center**
    - **57 requirements**
    - **~ 40 flow to Mission System Engineering at Project Level**
    - **GSFC developed tailored version – GPR 7123.1A**
        - **Mapping demonstrated**
        - **GSFC was audited in 2010 and is fully compliant**
    - **NPR 7123.1B update pending**

- **GOLD Rules**: Goddard Open Learning Design Rules
    - **Rules for the Design, Development, and Operation of Flight Systems**
    - **Compliance is Mandatory at Goddard**
    - **Contains engineering standards to be applied to projects**
    - **Compliance Matrix submission required at every Mission Review**
        - **MSE and CSO are responsible for enforcement and demonstrating compliance to GSFC**

GPR 7123.1A

Objectives and Constraints

Define Mission Environments

Operations Concept Development

Requirement Definition

Architecture & Design Development

Implementation

Integration (using Architecture)
Verification (using Requirements)
Validation (using Operations Concept)

Requirements Management

Technical Resource Budget Tracking

Risk Management

Trade Studies

Technical Baseline/Data Configuration Control

Interface Management

Technical Planning

Acquisition Support

Mission System with Objectives Met; Transitioned to Operations

NPR 7123.1 Technical Processes

Technical Management Processes

System Design Processes

Product Realization Processes

| 10. Technical Planning |
| 11. Requirements Mgt. |
| 12. Interface Mgt. |
| 13. Tech. Risk Mgt. |

| 14. Configuration Mgt. |
| 15. Tech. Data Mgt. |
| 16. Technical Assessment |
| 17. Decision Analysis |

1. Stakeholder Expectations Definition

2. Technical Requirements Definition

3. Logical Decomposition

4. Physical Solution

9. Product Transition

8. Product Validation

7. Product Verification

6. Product Integration

5. Product Implementation

Requirements Flow Down

On-Going Feedback

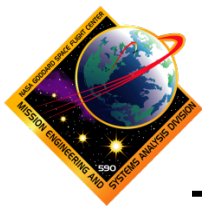**Realized Products**
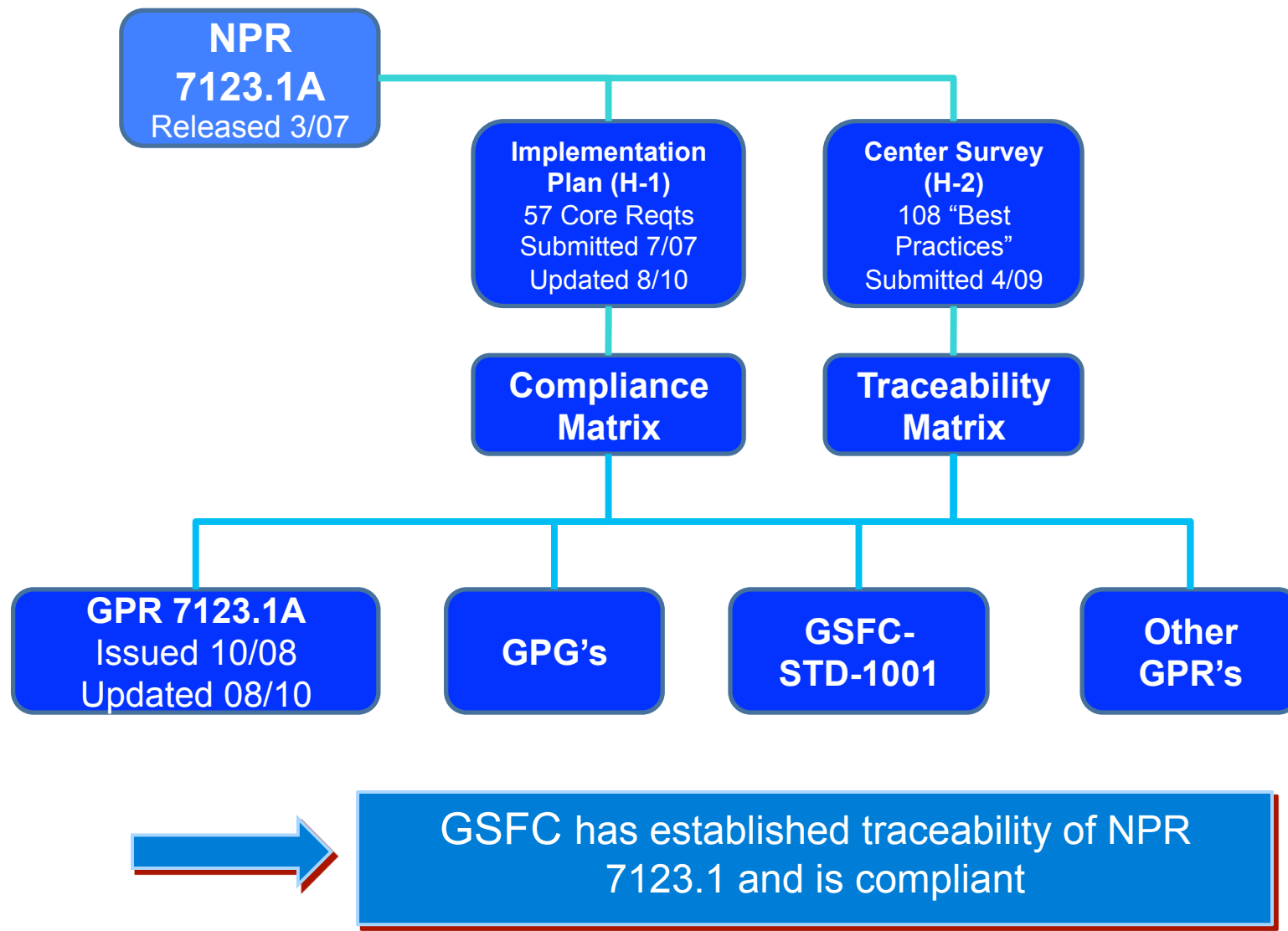
NPR 7123.1A to GPR 7123.1
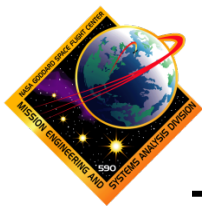## Process Mapping

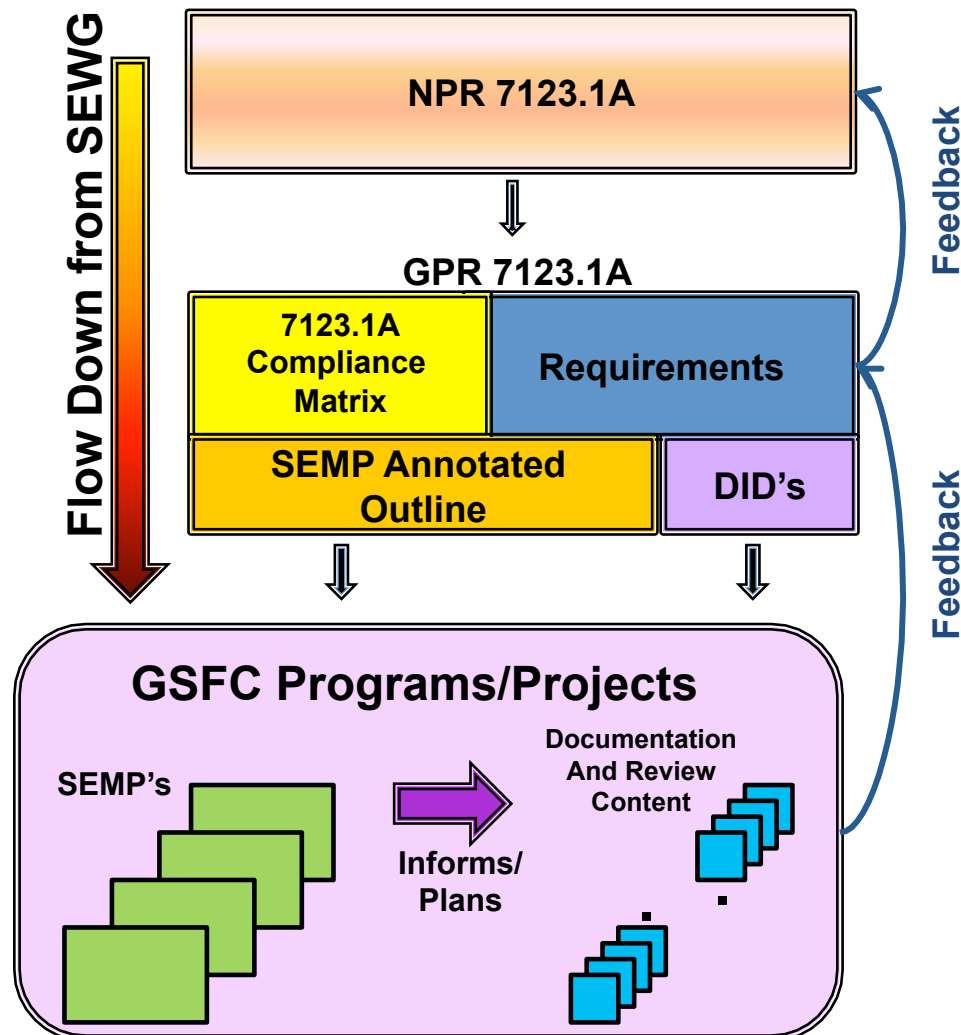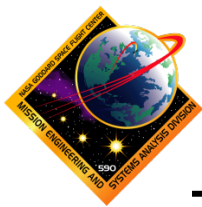| NPR 7123.1	GPR 7123.1
1. Stakeholder Expectations	4.1.1 Understanding the Objectives 4.1.2 Mission Environments 4.1.3 Operations Concept Development
2. Requirements Definition	4.1.4 Requirements Identification
3. Logical Decomposition	4.1.5 Architecture and Design Development
4. Design Solution	4.1.5 Architecture and Design Development
5. Product Implementation	4.1.6 Product Implementation 4.2.8 Acquisition Support
6. Product Integration	4.1.7 Integration
7. Product Verification	4.1.8 Verification
8. Product Validation	4.1.9 Verification
9. Product Transition	4.1.10 Product Acceptance and Transition
10. Planning	4.2.3 Technical Planning
11. Requirements Mgmt	4.2.1 Requirements Management
12. Interface Mgmt	4.2.2 Interface Management
13. Risk Mgmt	4.2.6 Risk Management
14. Configuration Mgmt	4.2.5 Configuration Management and Data Storage
15. Technical Data Mgmt	4.2.5 Configuration Management and Data Storage
16. Technical Assessment	4.2.4 Technical Resource Tracking 4.2.3 Technical Planning Milestone Reviews
17. Decision Analysis	4.2.7 Decision Analysis

How the NPR 7123.1A is Infused at GSFC

NPR 7123.1A
Released 3/07

Implementation Plan (H-1)
57 Core Reqts
Submitted 7/07
Updated 8/10

Center Survey (H-2)
108 "Best Practices"
Submitted 4/09

Compliance Matrix

Traceability Matrix

GPR 7123.1A
Issued 10/08
Updated 08/10

GPG's

GSFC-STD-1001

Other GPR's

→ GSFC has established traceability of NPR 7123.1 and is compliant

How the NPR 7123.1A Flows Down

Competing Objectives

Academia
"Eye On Process"

Practitioners
"Eye On Products"

NPR

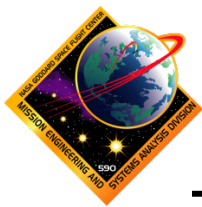Shelfware SEMP's

GPR

More Focus on Product
- GPR written w/ product focus
- Provide examples
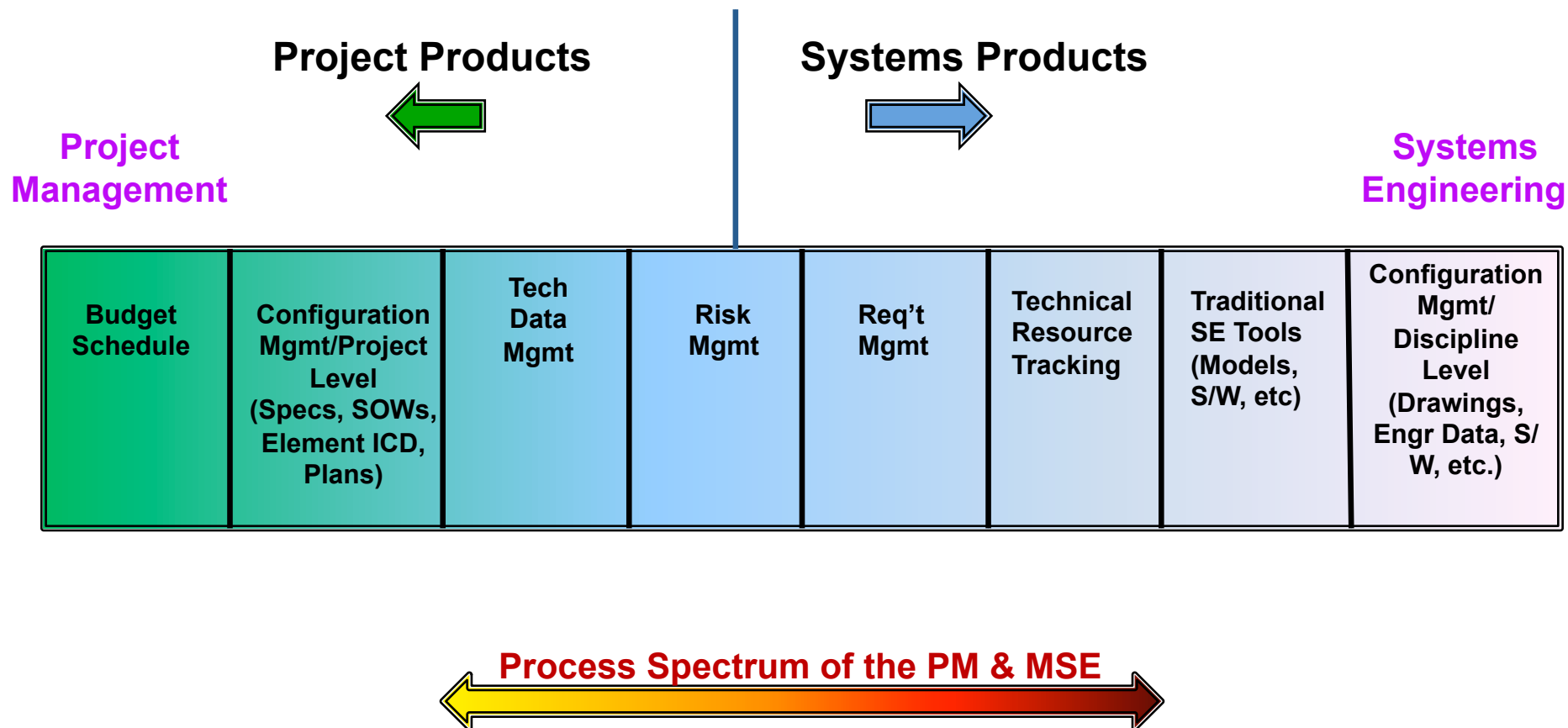- Bringing SE to projects (assistance; training)
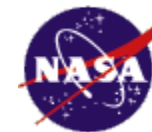
Increase Focus on Process
- Awareness/Value of GPR, GPG's
- SEMP rewrites
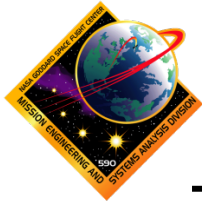- Develop Processes to follow
- DID conformance

- **Consistent Processes & Documents**
- **SEMP's to "live by"**
- **7123.1 Compliance**

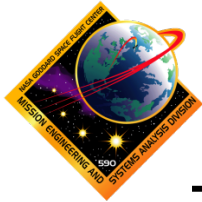**Objective**

Process/Product Spectrum

Project Products ⬅️   **Systems Products** ➡️

Project Management   **Systems Engineering**

Budget Schedule	Configuration Mgmt/Project Level (Specs, SOWs, Element ICD, Plans)	Tech Data Mgmt	Risk Mgmt	Req't Mgmt	Technical Resource Tracking	Traditional SE Tools (Models, S/W, etc)	Configuration Mgmt/ Discipline Level (Drawings, Engr Data, S/W, etc.)

⬅️ **Process Spectrum of the PM & MSE** ➡️

A Word About "Products"

What are Systems Engineering Products?

- **Reviews**

- **Plans**

- **Technical Documents**

- **Successful Mission Executed**

Processes lead to ESSENTIAL products for MISSION SUCCESS
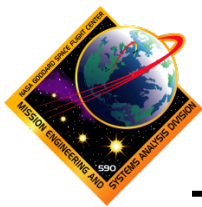
Processes

Understanding the Objectives
Operations Concept Development
Architecture & Design Development
Requirements Identification and Management
Validation and Verification
Interface Management
Mission Environments
Technical Resource Budget Tracking
Risk Management
System Milestone Reviews
Integration and Product Acceptance
Acquisition Support
Decision Analysis
Configuration Management

Products

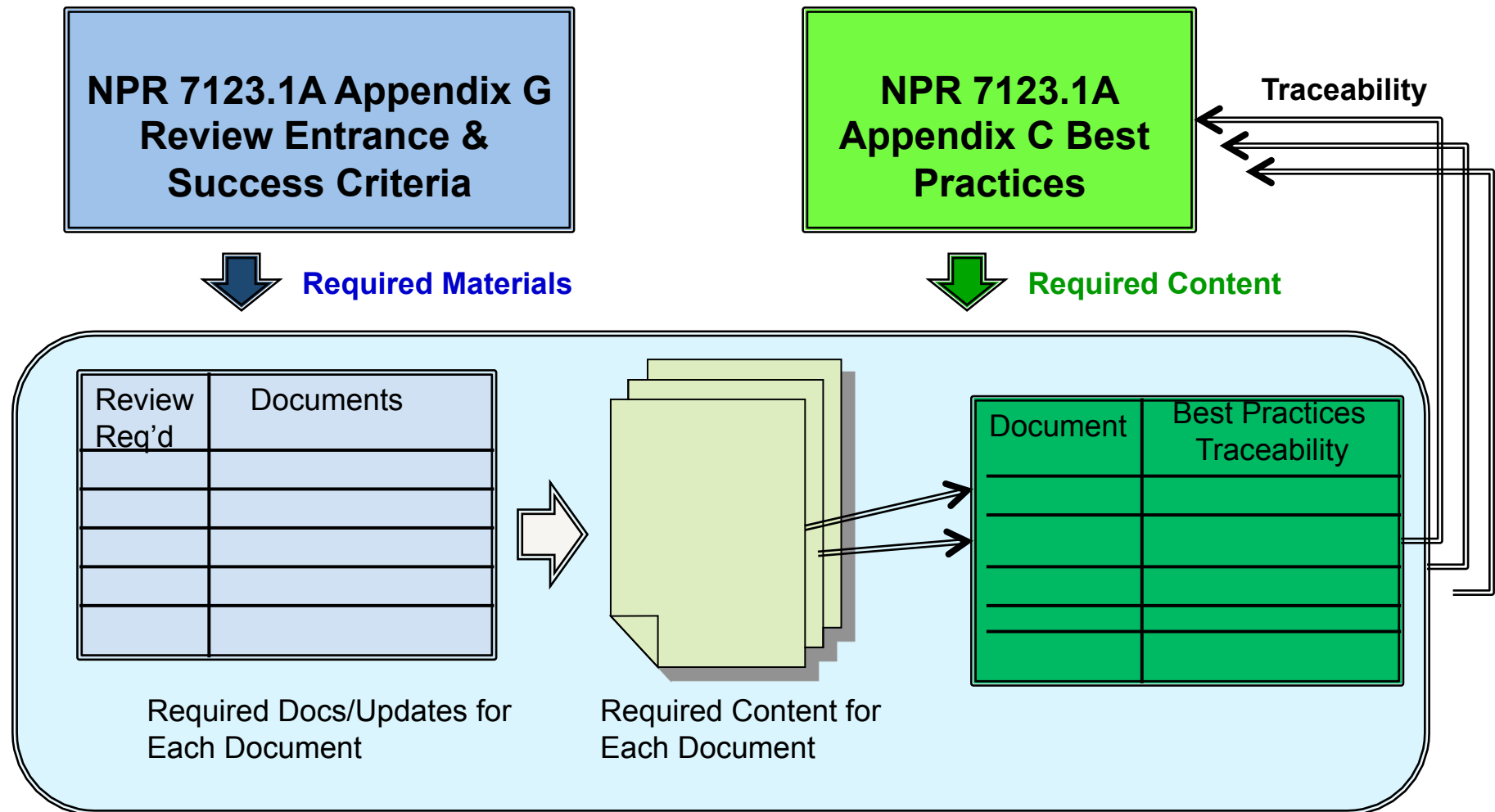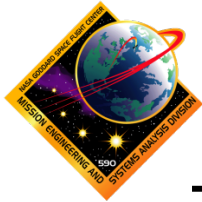| |
|---|
| Level I Requirements Document |
| Operations Concept Document |
| Architecture Description Document
Design Specifications |
| Level II/III/… Requirements
Requirements Database |
| I&T Strategy
I&T Plan
Requirements Verification Traceability Matrix |
| IRDs, ICDs |
| MAR
Mission Environment Plan |
| TPM's |
| Risk Management Plan
Risk Tracking/Reporting |
| Systems Review Plan |
| Systems Integration Plan
Transition to Operations Plan |
| SOW, RFP, CDRL, DID's, etc. |
| Trade Study Plans
Trade Study Reports/data capture |
| CM Plan
Technical Data Storage
Project Documents |

Mission Success
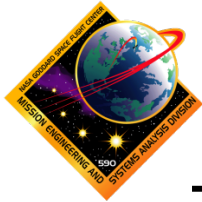
Document Updates/Continuum For SE Lifecycle

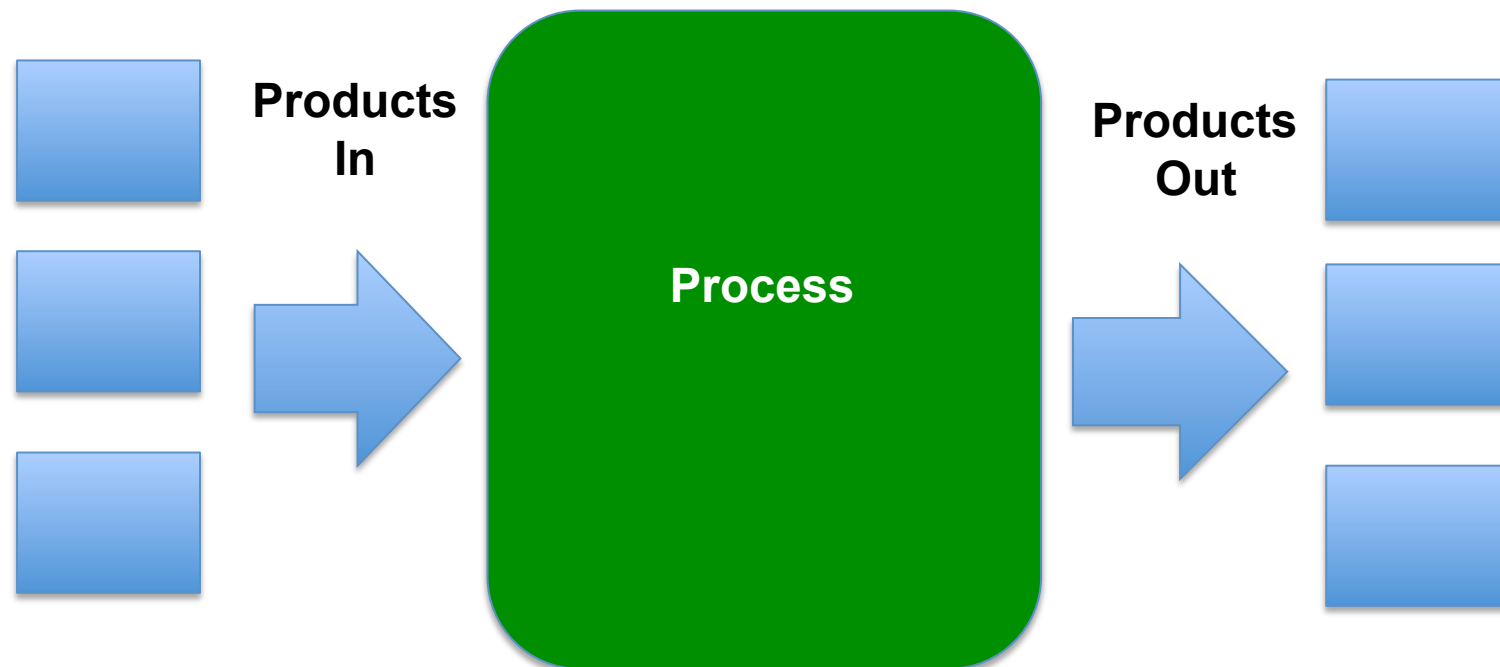| Key Function	Where Typically Documented	Pre-Phase A — Concept Studies	Phase A — Preliminary Analysis	Phase B — Definition	Phase C — Design	Phase D — Development	Phase E / F — Operations
4.1.1 Understanding the Objectives	Level I Requirements Document	Concept	Baseline	Complete (Note 1)	Track Changes	Track Changes	Track Changes
4.1.2 Mission Environments	Environmental Test Plan / Orbit Debris Analysis	Initial	Baseline	Complete	Track Changes	Track Changes	Track Changes
4.1.3 Operations Concept Development	Concept of Operations Document / Operations Plan	Concept	Baseline	Refine	Complete	Track Changes	Track Changes
4.1.4 Requirements Identification	Level II Requirements Document / Level N Requirements Documents	Concept	Top Level Baseline	Complete	Track Changes	Track Changes	Track Changes
4.1.5 Architecture & Design Development	Architecture Description Document / Design Documentation / System Drawings	Concept	Baseline	Complete	Track Changes	Track Changes	Track Changes
4.1.6 Product Implementation	Subsystem Descriptions / As-built Documentation		Concept	Concept	Baseline	Complete	
4.1.7 Integration	Integration Plan / Integration Procedures	Concept	Concept	Initial	Develop Plans	Complete	
4.1.8 Verification	Verification Plan / RVTM	Concept	Initial	Assign Method	Develop Plans	Complete	
4.1.9 Validation	Validation Plan / RVTM	Concept	Initial	Assign Method	Develop Plans	Complete	
4.1.10 Product Acceptance & Transition	Acceptance Plan / Transition Plan	Concept	Concept	Initial	Baseline	Track Changes	Complete
4.2.1 Requirements Management	Requirements Management Plan (SEMP) / Reqts Database	Concept	Baseline	Complete	Track Changes	Track Changes	
4.2.2 Interface Management	IRD's / IDD's / ICD's	Concept	Initial (Note 2)	Baseline	Complete	Track Changes	
4.2.3 Technical Planning	SEMP	Concept	Initial	Baseline	Complete	Track Changes	
4.2.4 Technical Resource Budget Tracking	Resource Budgets (MSR)	Concept	Initial	Baseline	Track Changes	Track Changes	Track Changes
4.2.5 Configuration Management and Data Storage	CM Plan / CM'd Products / Technical Data Products	Informal CM	Control Level 1 Requirements	Start Formal CM	Track Changes	Track Changes	Track Changes
4.2.6 Risk Management	Risk Mgmt Plan / Risk Database (MSR)	Estimate	Draft FTA, RBD	Preliminary FMEA, 2nd FTA, RBD	Baseline FTA, FMEA, RBD, PRA	Update Changes	Update Changes
4.2.7 Decision Analysis	Trade Study Reports / SEMP (Major Trades)	Apply as Needed					
4.2.8 Acquisition Support	SOW, Contract	Develop SOW	Evaluate Proposal(s)	Technical Oversight & Reviews			
5.0 System Milestone Reviews (Note3)	Review Packages	MCR	SRR, MDR	SCR, PDR,	CDR, SIR	MOR, TRR (PER), FOR, PSR, FRR, ORR	PLAR, CERR, DR

Infusing Standards through Products

Review Req'd	Documents

NPR 7123.1A Appendix G Review Entrance & Success Criteria

⬇ **Required Materials**

NPR 7123.1A Appendix C Best Practices

⬇ **Required Content**

Traceability

Required Docs/Updates for Each Document

Required Content for Each Document

Document	Best Practices Traceability

599-PG-7123.1.1 SE Data Item Descriptions (DRAFT)

Anatomy of a Process

Products In → **Process** → **Products Out**

Processes are being done whether they are written down or not
In order to generate products, a process is used
The question is: is it repeatable? Is it agreed upon? Is it known?
People invent processes and localize them if they are not flowed down
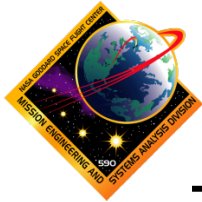Example: Configuration Management

Vanilla Project "V"

Mission Objectives

Transition to Operations

MCR

ORR, PSR,
MRR, SMSR, Launch

Architecture, ConOps, Requirements

Integration, Verification, Validation

SRR

SIR, PER, TRR

PDR

Design

Deliver

CDR

PSR (lower levels)
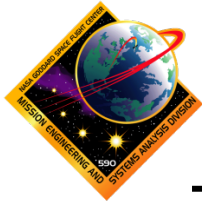
Fabricate/ Code
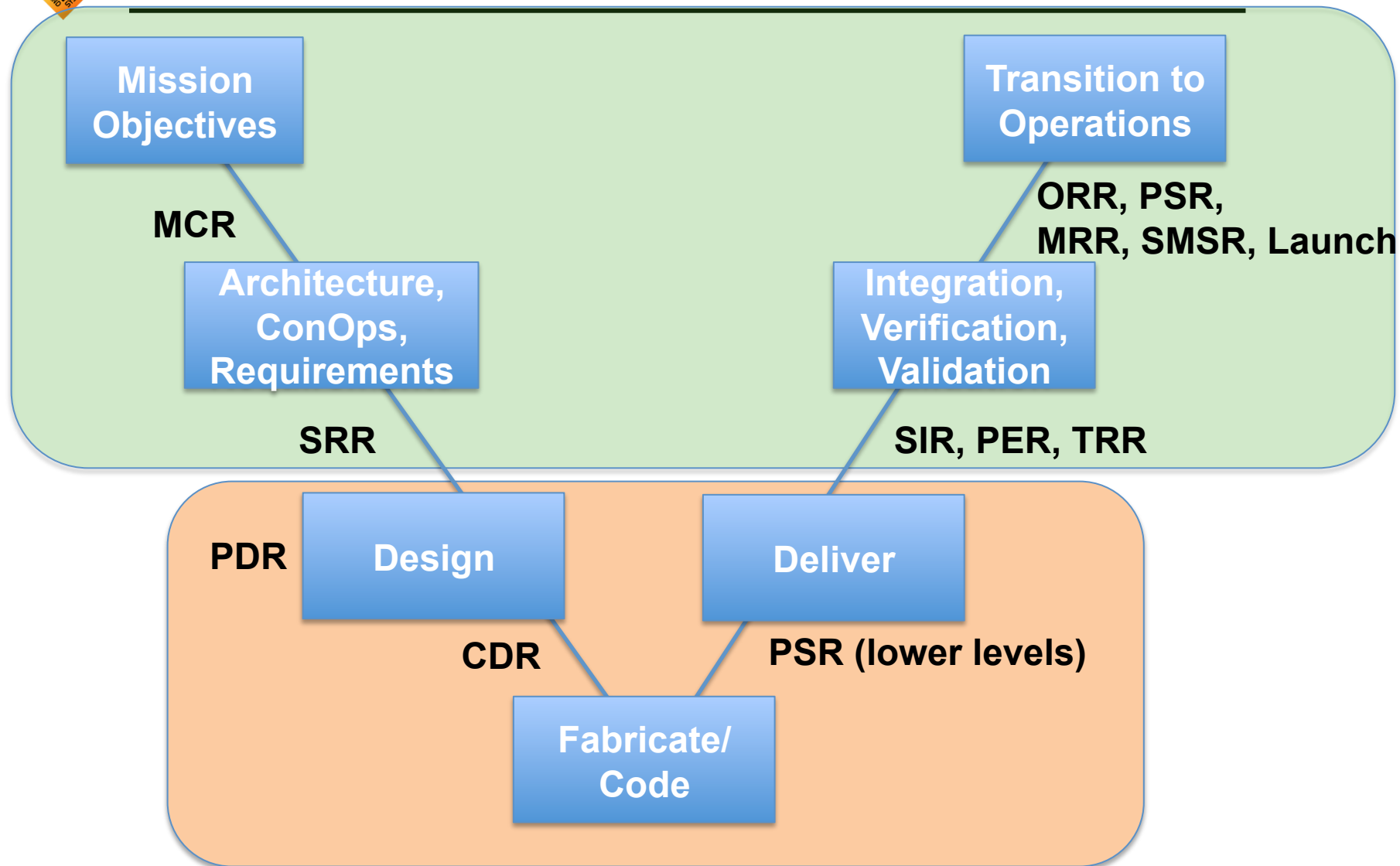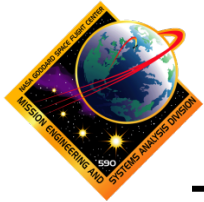
Systems Engineering Planning

Planning

General George S. Patton
1885-1945

"A good plan executed today is better than a perfect plan executed at some indefinite point in the future."

"A pint of sweat will save a gallon of blood."

"Never tell people how to do things. Tell them what to do and they will surprise you with their ingenuity."

" In the space of two days I had evolved two plans, wholly distinct, both of which were equally feasible. The point I am trying to make is that one does not plan and then try to make circumstances fit those plans… one tries to make plans fit the circumstances."
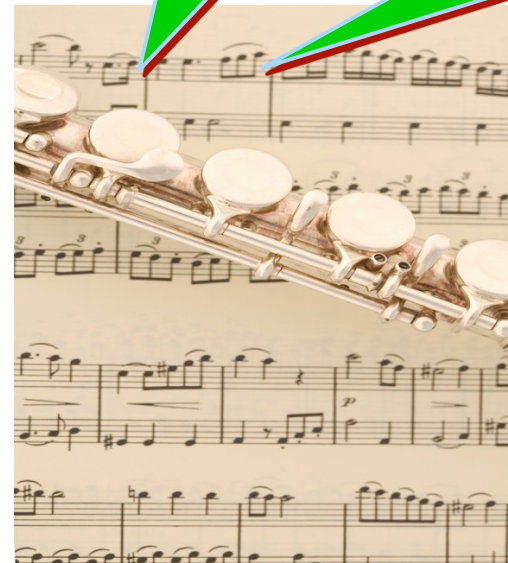
Develop the Plan, Document the Plan, Follow the Plan (Edit the Plan)
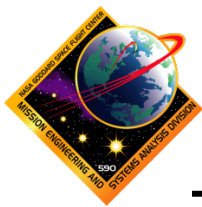
- **Playing an instrument is an exercise in planning**

- **Developing a Plan/Planning is underrated!**

- **Everyone on a project is involved to some degree in the SE effort**

Developing Plans and Documents

Discussions/ Agreements with Stakeholders

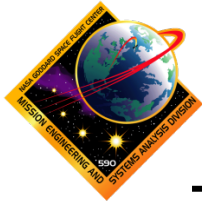**Brainstorming with the Team/Peers**

Presenting to the team

Getting all parties buy-in

Systems Engineering is a TEAM effort!

Communicating for execution

Planning Fundamentals

- **What is a SEMP?**
  - *Systems Engineering Management Plan*
  - **Establishes a contract between the Project SE team, the PM and DGA as to how the SE team will facilitate the implementation effort**
  - **Communicates The Plan (*processes/activities*) to accomplish the mission *products* required**
  - **It's the key source to coordinate technical planning**
- **Why develop a SEMP?**
  - **A lot of folks view writing a SEMP as an impediment to "doing real work" but the lack of one can result in:**
    - **Lack of clear R&R's within a project; i.e. duplication of efforts, holes in activities;**
    - **Lack of orchestration within a project; i.e. localized processes emerging, etc.**
  - **Developing and Publishing a SEMP:**
    - **Actually streamlines "doing real work" and increases team productivity.**
    - **Encourages/fosters the type of communication that is needed within a project; MSE/PM; MSE/Technical Team**
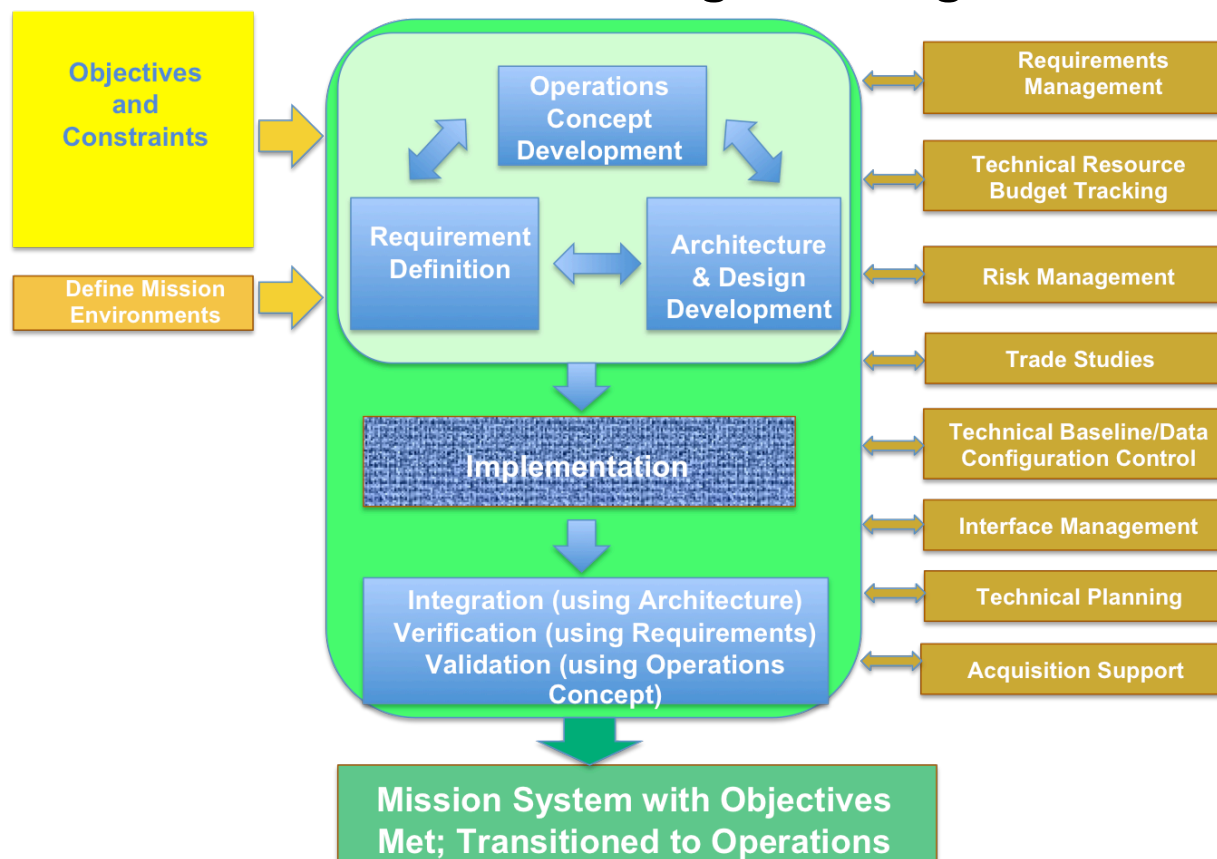   - **Ensures common processes are defined and followed across entire project**
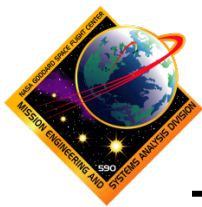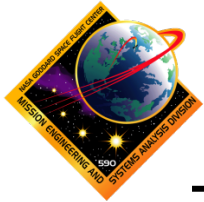
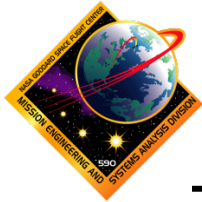# Let's Make a Plan

…. And Stick to it

The plan should be sized to the job

Installing a Ceiling Fan

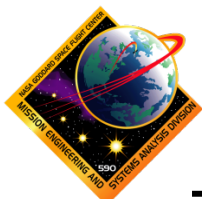# Application of SE Standards:

NPP Phase D

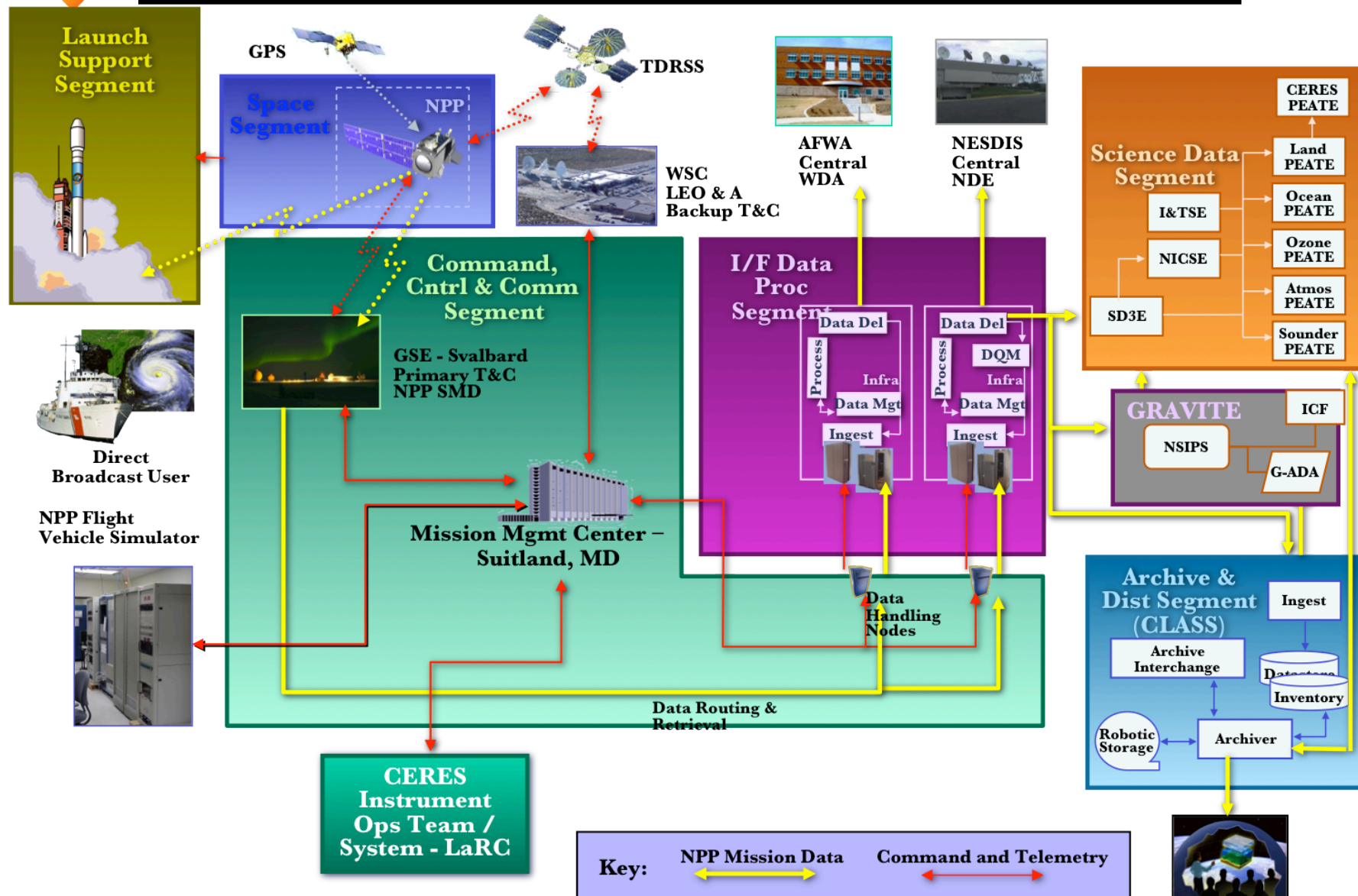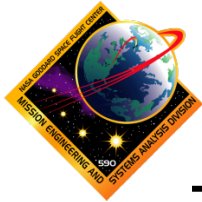# How to Perform V&V in a Rapid, Efficient fashion

- **Create an agreed upon plan/process (this is the hard part, but pays off)**
- **Put together the right team**
- **Get the Requirements Documents up to date**
- **Get the Concept of Operations up to date**
- **Continuously evaluate process and implement improvements**
- **Communicate status, progress and process changes (all the time)**
- **Run tests or find events that can be used until you close all of the requirements**

NPP: 516 Level 2 Requirements; 0 closed Program transfer of ownership to NASA late in the Game
Start Date on NPP: 2/1/2011
First Requirement Closed: 3/25/2011
Requirement # 505 Closed: 10/17/2011; 11 planned for post launch
**Launch: 10/28/2011**

NPP Mission System Architecture

GSFC SE Seminar

11/8/2012

Slide 32

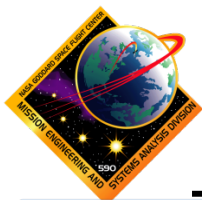# GPR 7123.1A Process Status (Feb/Sept)

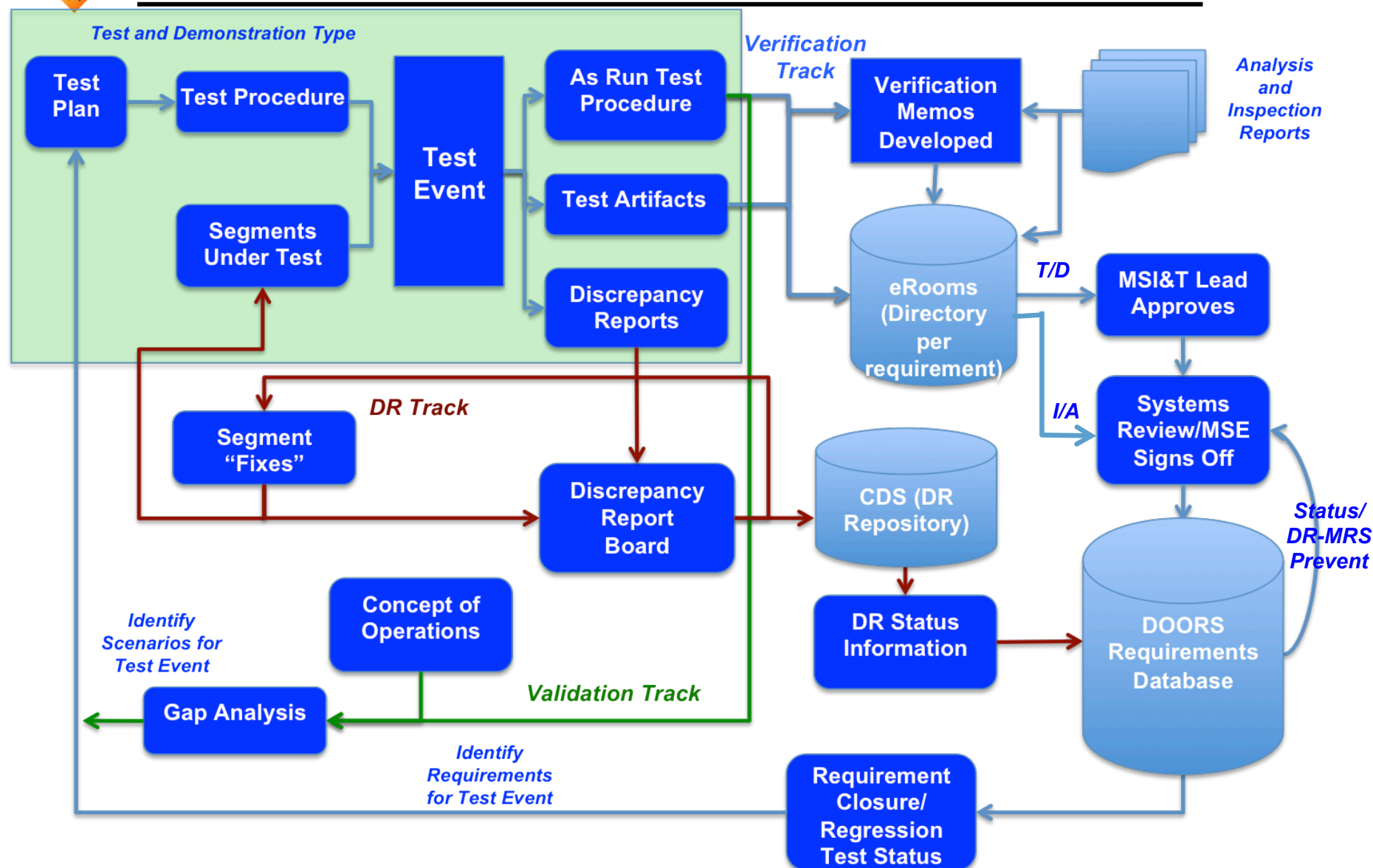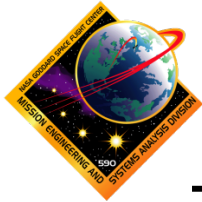| Key Function	February	October
4.1.1 Understanding the Objectives	Completed	No change
4.1.2 Mission Environments	Defined; Environmental Testing In Progress	Completed successfully
4.1.3 Operations Concept Development	Stale	Up to date - 2 revisions completed
4.1.4 Requirements Identification	Requirement Set required edits to accommodate as-built system/system evolution/new needs	Requirement Set up to date
4.1.5 Architecture & Design Development	Completed (addition of GRAVITE not architecturally independent of IDPS)	Common drawing in use
4.1.6 Product Implementation	Segment builds/repairs/workarounds being delivered for I&T	Launch deliveries complete
4.1.7 Integration	Incremental; ongoing	System fully integrated with Launch builds
4.1.8 Verification	0 Reqts signed off; Requirement document needed revision for test events; criteria/artifact definition required test planning overlapping test events	505 signed off; 7 Test Events completed
4.1.9 Validation	ConOps stale; no linkage or validation to Test/Rehearsal program	TYLF analysis complete; fed back to Test/Rehearsal program while in progress; validation to ConOps complete
4.1.10 Product Acceptance & Transition	Team/product integration underway	Operations team/products ready for launch
4.2.1 Requirements Management	DOORs being set up; linkages not validated/various established	DOORS up to date with current MRS, verification status; links validated (within contractual boundaries)
4.2.2 Interface Management	JPSS; documents at various maturity levels	Joint NPP/JPSS; NPP items signed off/verified
4.2.3 Technical Planning	Phase: Mission V&V; needed planning; SEMP stale	Plan developed & executed; SEMP revised
4.2.4 Technical Resource Budget Tracking	On Track; within margins	Ready for Launch
4.2.5 Configuration Management and Data Storage	SEWG process in place; Docushare, eRooms being configured	SEWG & CCB process in place; eRooms fully configured/employed; Freeze in place
4.2.6 Risk Management	Strong Risk process in place	Risks mitigated/defined
4.2.7 Decision Analysis	Trades outstanding, ongoing	Trade results implemented and documented
4.2.8 Acquisition Support	Established, in motion (combination JPSS/NPP)	No change in process; contracts in force
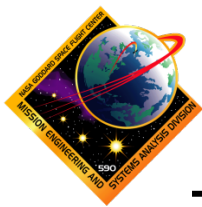
The Progress

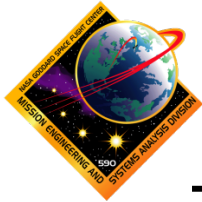| Area	February-11	October-11
Requirements Signed Off (Total: 516)	0	505
Mission Requirements Specification (L2)	Revision A	Revision C CH-02
Mission Concept of Operations	Rev - (2004 Version)	Revision B Up to Date; Validated
Systems Performance Verification Plan	Rev - (2001 Version)	Revision A Up to Date; Executed
Mission Discrepancy Report Board	Rebooting; DR/MRS not connected	Fully functional; DR/MRS connected
Interface Management/Verification	Under JPSS; verification not defined	NPP/JPSS; 5 point verification
ICD's and IRD's	Various maturity, format, content	Up to Date; verified
I&T Team	Recently Reorganized	Integrated Effort with SE
Upcoming Test Events	NCT3P1, NCT3P2, NCT4, 36HT, MR4, 14DT	None; Launch on 10/28
Verification Plans/Requirement	Establishing	Plan executed; Defined burndown for each
Requirement to Test mapping	I&T	SE
Level 3 Requirements (Segments)	Independent of Level 2	Integrated L2/3 SE Effort with Burndown Tracking
Verification/Sign Off Process/DOORs	Not established	Pre-launch complete; Up to Date
Level 2/3 Requirement links	Not validated/established	Validated/Established
Collision Avoidance	CRAT governance	CARA governance; CARA/CRAT combined ops; CATDD; Verified and Validated
Team	2 S/C + 1 new	10 peak; 4 10/17
Reviews	Last Review: MOR (Nov '10)	Completed: FOR, PSR, ORR, MRR

The Process

Test and Demonstration Type

- Test Plan
- Test Procedure
- Segments Under Test
- Test Event
- As Run Test Procedure
- Test Artifacts
- Discrepancy Reports

Verification Track

- Verification Memos Developed
- *Analysis and Inspection Reports*
- eRooms (Directory per requirement)
- *T/D*
- MSI&T Lead Approves
- *I/A*
- Systems Review/MSE Signs Off
- *Status/ DR-MRS Prevent*

DR Track

- Segment "Fixes"
- Discrepancy Report Board
- CDS (DR Repository)
- DR Status Information
- DOORS Requirements Database

- Concept of Operations
- *Identify Scenarios for Test Event*
- Gap Analysis
- *Validation Track*
- *Identify Requirements for Test Event*
- Requirement Closure/ Regression Test Status

Application of SE Standards:

ASTRE Phase A

GPR 7123.1A Progress (2012)

Process	Phase A Progress
1. Understanding the Objectives	Level 1 Requirements Developed
2. Mission Environments	AEVR Developed
3. Operations Concept Development	Operations Concept Document Completed Concept Study Report Completed
4. Requirement Definition	Level 2 Requirements Developed
5. Architecture & Design	Architecture Description Document Completed
6. Implementation	N/A (Heritage Systems built to print)
7. Integration	Integration, Verification & Validation Plan Developed
8. Verification	
9. Validation	
10. Transition to Ops	Strategy developed
11. Technical Planning	2 Revisions of SEMP issued
12. Requirements Mgmt	DOORs ingest of L1's, L2's, linkages validated
13, I/F Mgmt	ICD's templates/drafts
14. Technical Risk Mgmt	Risk Mgmt Plan complete, Risk Board instantiated
15. Tech Data Storage	Sharepoint site configured; technical data vaulted
16. Technical Decision	Phase A Trades completed, documented; Phase B Trades identified
17. Acquisition Support	SOW's completed with CDRL's/ DID's identified

Peer SRR/MDR: 4/17-18/12 (NPR 7123.1A Compliant)
Concept Study Report Submitted: 9/21/12

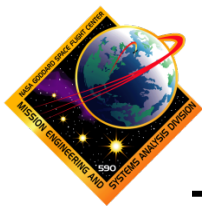# How to get Requirements written in a Rapid, Efficient fashion

- Get stakeholders involved immediately
- Start with a picture to get things going
- If you don't start with a picture, everyone has one in their own head
- Keep updating it until everyone agrees
- Get descriptions of everything in the picture
- Define terms of decomposition
- Define levels of architecture
- Call it the **Architecture Description Document**
- **Keep updating it**

- Record the use cases while folks are talking about the picture and put it in a document, send it out
- If you don't write it down, everyone has their own versions in their head
- Keep updating it until everyone agrees
- Call it the **Concept of Operations**
- **Keep updating it**

Now write the requirements. (and keep updating them)

**Start Date on ASTRE: 1/6/2012
First drop of Level 1's: 2/10/2012
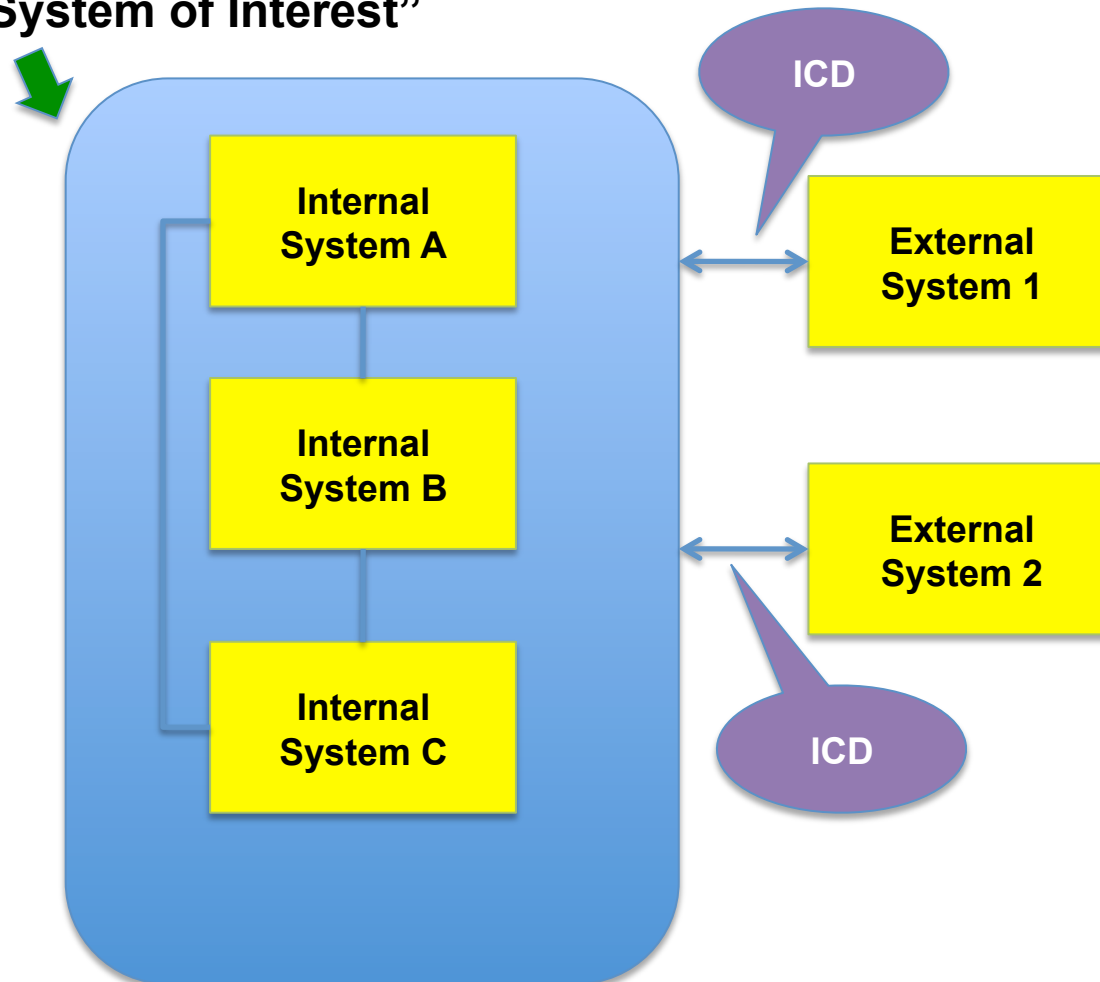First drop of Level 2's: 2/27/2012**

Then write the Integration, Verification and Validation Plan Using the ADD for Integration, Requirements for Verification and the ConOps for Validation
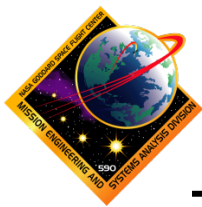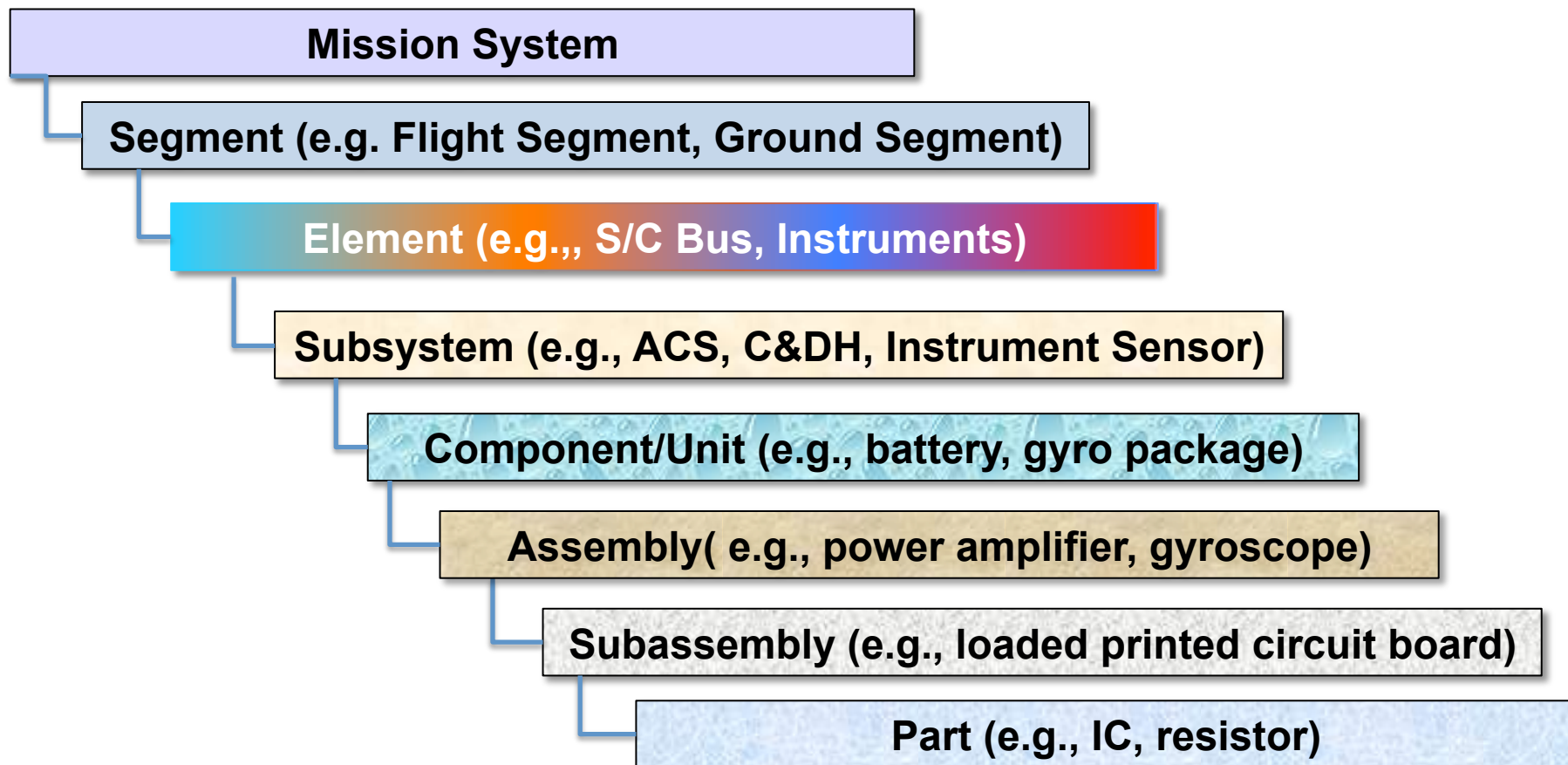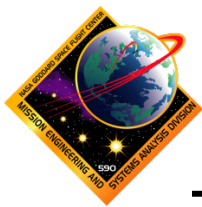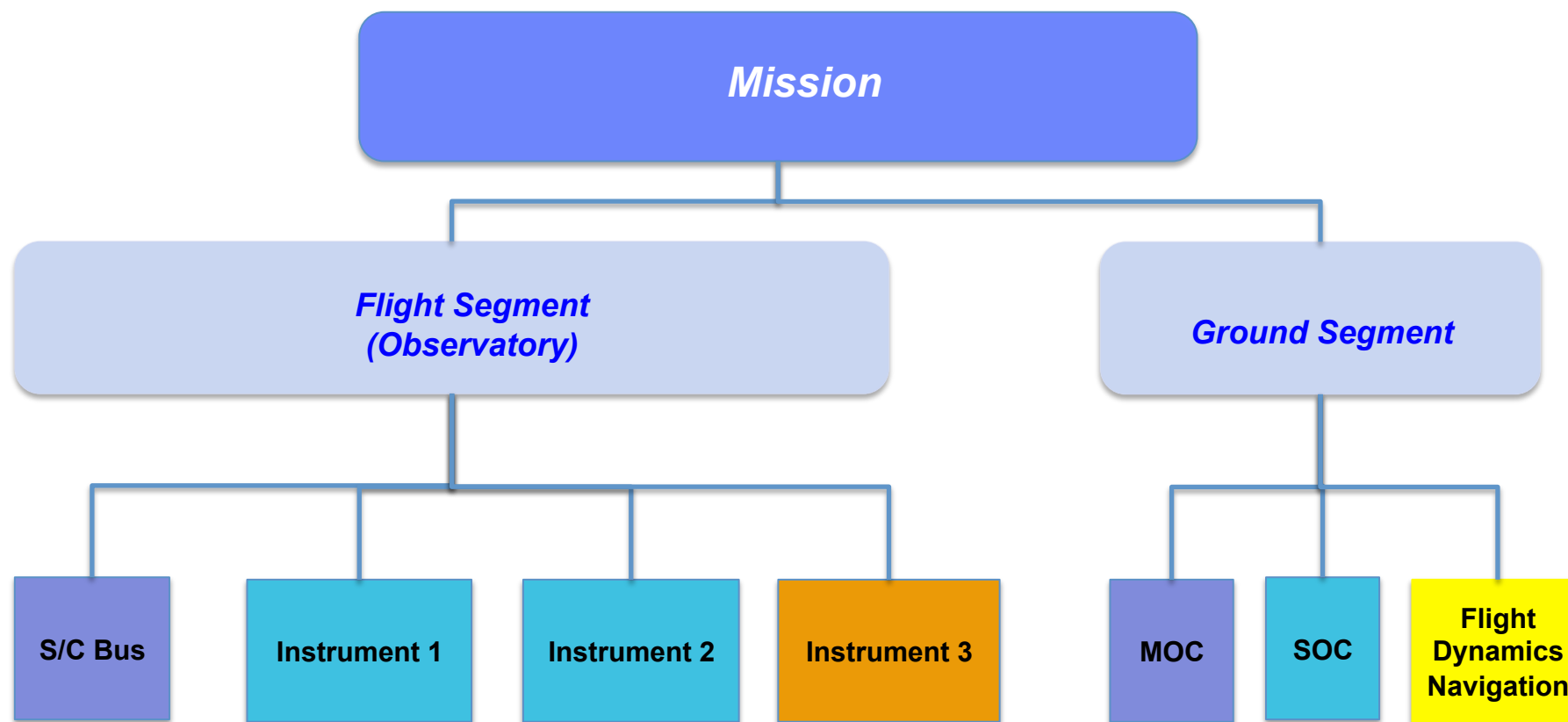
Creating a Context
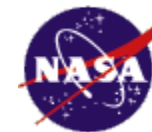
The "System of Interest"

* Also identifies Stakeholders

Creating a Hierarchy and Architecture

Mission System

Segment (e.g. Flight Segment, Ground Segment)

Element (e.g.,, S/C Bus, Instruments)

Subsystem (e.g., ACS, C&DH, Instrument Sensor)

Component/Unit (e.g., battery, gyro package)

Assembly(e.g., power amplifier, gyroscope)

Subassembly (e.g., loaded printed circuit board)

Part (e.g., IC, resistor)

Generic Architecture
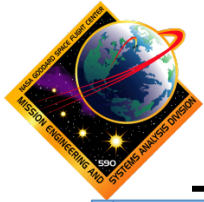
Setting up the Requirements Management System

L1

Ingest Document (original)
Generate Document

L1 RVTM

Ingest Traces, V&V
Reports, Status

L2

Ingest Document (original)
Generate Document

L2 RVTM

Ingest Traces, V&V
Reports, Status

Element Level

ERD's → **Element RVTM's**

Ingest/ Validate

RVTM's DOORS Ready

DOORS Mission Requirements Database

Ingest Document (original)
Generate Document

ICD's

External and Inter-Element ICD's are Project Developed with Element Participation

Verification
Reports, Status

ICD Verif Matrices

Application of SE Standards:

Example Project

Project Information

Project Information:

Customers (Ken and Karen) – It's their house; willing to pay $50K want it done by Christmas

PM (Mike) – Owns the remodeling company; allocates the budget, ensures we make schedule, makes sure Susan and Kevin are on track
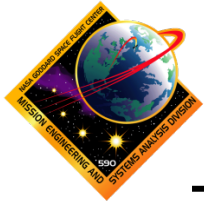
MSE (Susan): Develops (extracts from the customer) the requirements, develops the ConOps, and designs the kitchen architecture then communicates the vision and ensures the vision is implemented

Development Mgr (Kevin) – builds the kitchen to meet the requirements/design/ConOps, responsible for day to day operations of the remodel

Staff Available:
- **Demolition Crew**
- **Electrician**
- **Carpenter**
- **Plumber**
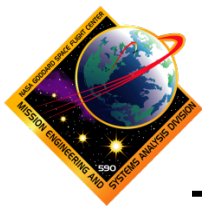- **Procurement (cabinets, flooring, countertops, appliances, fixtures)**

Modern, Window view, new appliances

Easy to maintain, $$ $??? Easy to use

Karen

Ken
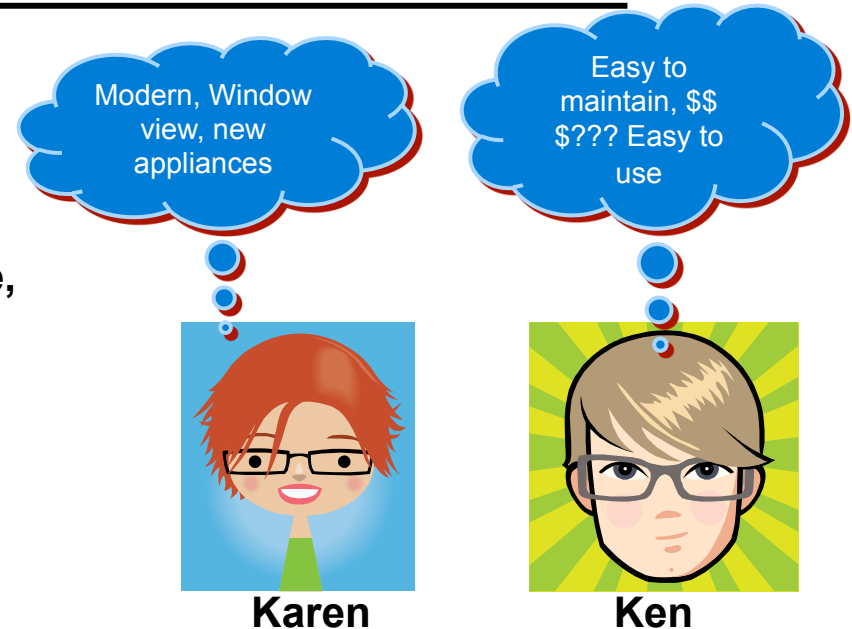
Sample Project: Remodeling the Kitchen

- ❑ **Objectives and constraints?**
- ❑ **Environment?**
- ❑ **Technical resource budgets?**
- ❑ **Risks?**
- ❑ **Trades?**
- ❑ **Interfaces?**

GPR 7123.1A

Objectives and Constraints

Define Mission Environments

Operations Concept Development

Requirement Definition

Architecture & Design Development

Implementation

Integration (using Architecture) Verification (using Requirements) Validation (using Operations Concept)

Requirements Management

Technical Resource Budget Tracking

Risk Management

Trade Studies

Technical Baseline/Data Configuration Control

Interface Management

Technical Planning

Acquisition Support

Mission System with Objectives Met; Transitioned to Operations
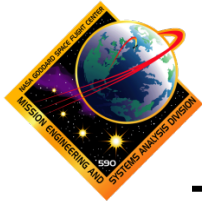
Roundup

- **Requirements are Essential!**
- **Systems Engineering is a Team Effort**
- **Process is simply a definition of the work to be done**
- **If a process isn't working, change it!**
- **Planning and Communication is Key**
- **Putting Standards into Action not only Works but is Effective once you learn how to use them**

Reference Materials

- **NPR 7123.1A, NASA Systems Engineering**
- **GPR 7123.1A, GSFC Systems Engineering**
- **SP-6105, NASA Systems Engineering Handbook**
- **599-PG-7123.1.1 SE Data Item Descriptions (DRAFT)**
- **GSFC-STD-1000 GSFC Rules for the Design, Development, Verification, and Operation of Flight Systems (GOLD Rules)**
- **GSFC-STD-1001 GSFC Criteria for Flight and Flight Support Systems Lifecycle Reviews**
- **GSFC-STD-7000 GSFC Environmental Verification Standards**
- **NPR 7120.5E NASA Program and Project Management**
- **320-MAR-1001 Rev. D Standard Mission Assurance Requirements**