Systems Engineering Approach for the Orion Pad Abort-1 Flight Test

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Outline

- PA-1 Introduction (short video)
- PA-1 Roles & Responsibilities & System Providers
- Gathering inputs from Parent Stakeholders
- Organizing the project to build the system – (project-centric culture)
- Project Structure used to cross communicate
- Defining the system architecture & requirements
- PA-1 Lifecycle approach
- Verification approach
- Conclusions

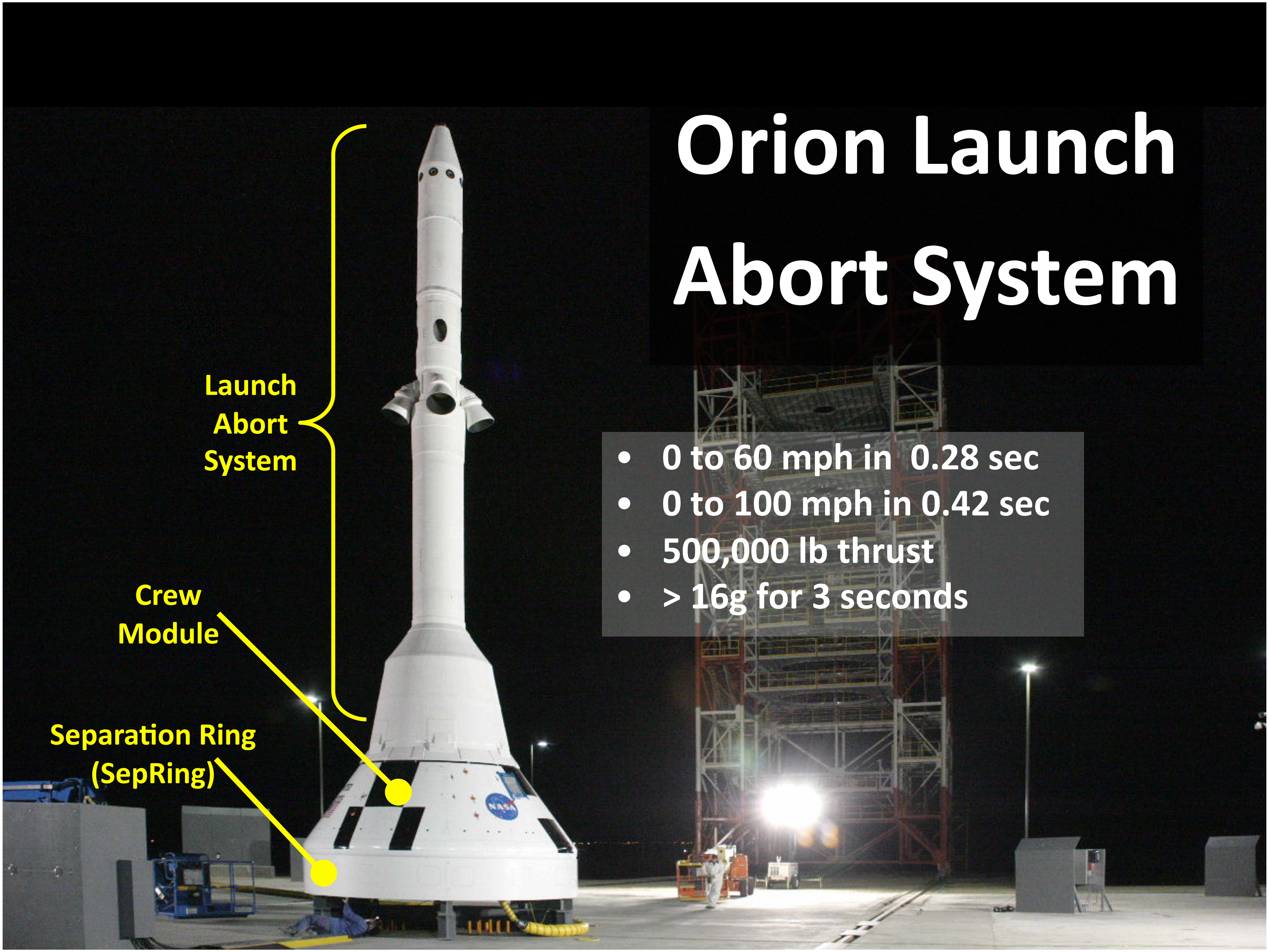
NOTE: Lessons learned embedded throughout presentation

Presentation Context

- Slides also intended to serve as a future use reference
  - Slides will tend to have more stand-alone wording
- Will not delve into specific SE data base tools, Config. Mgmt. processes, etc…
  - PA-1 Project did have Config. Mgmt. process, Risk Mgmt. processes, problem reporting process, data base tool (for requirements traceability & verification tracking),
  - Focus more on basic approaches & lessons learned rather than specific process & tools
- Made approach & lessons learned more generalized - apply to most SE challenges
- Address the human element in implementing a SE approach across a project

Lamborghini

- 0 to 60 mph in 3.8 sec
- 0 to 100 mph in 8.6 sec
- 631 horsepower

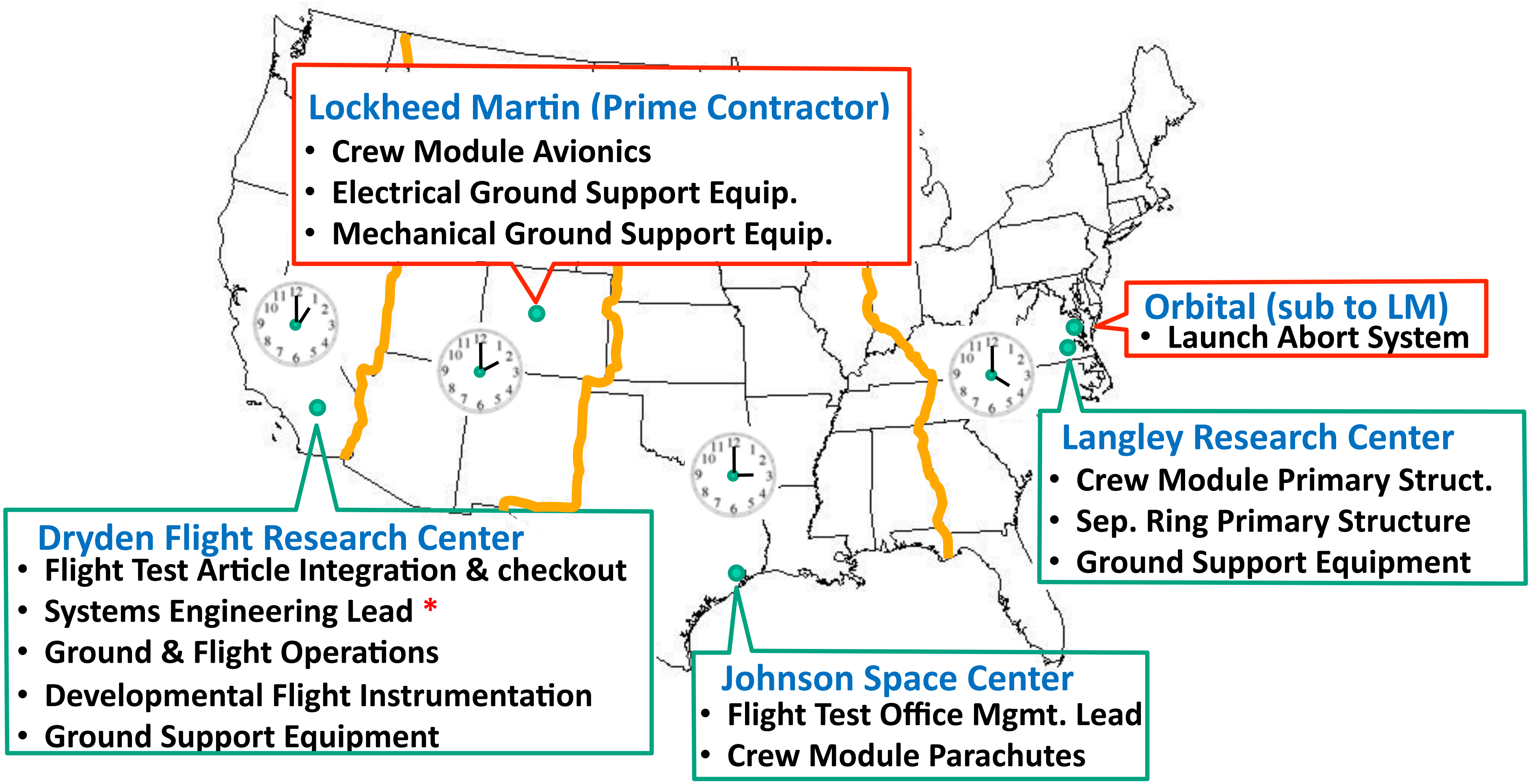

Orion Launch Abort System
• 0 to 60 mph in 0.28 sec
• 0 to 100 mph in 0.42 sec
• 500,000 lb thrust
• > 16g for 3 seconds
Launch Abort System
Crew Module
Separation Ring (SepRing)
NASA

Insert Pad Abort – 1 launch video here!!!

- *From: www.vimeo.com/11631855*

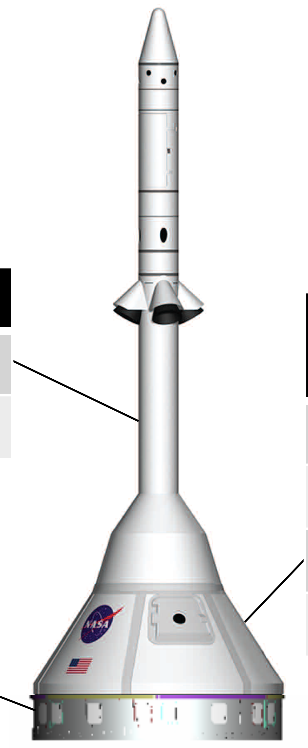
PA-1 Project-Wide Roles & Responsibilities

(spanned across 4 time zones)



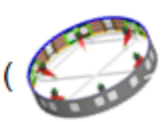
PA-1 Flight Test Article & Providers

Launch Abort System (LAS)	
Provider	LM (Prime contractor)
	Orbital (Subcontractor)



Crew Module (CM) Subsystem	Provider
Structure	LaRC (Govt)
Avionics	LM (Contractor)
Instrumentation	DFRC (Govt)
Parachutes	JSC (Govt)

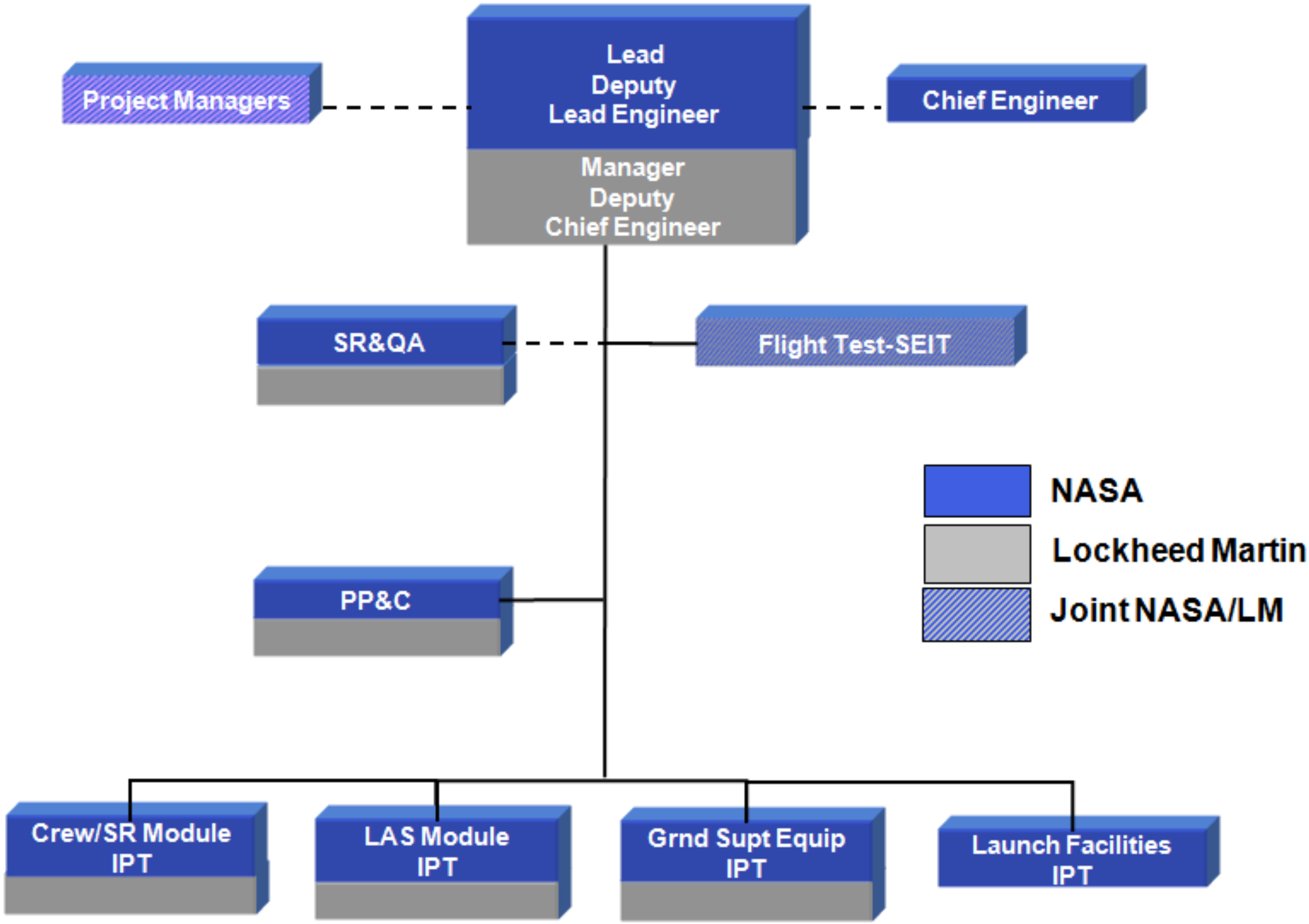
Separation Ring	
Structure	LaRC (Govt)

Flight Test Article (FTA) = LAS () + CM () + SepRing () = 

Launch Abort Vehicle (LAV) = LAS + CM

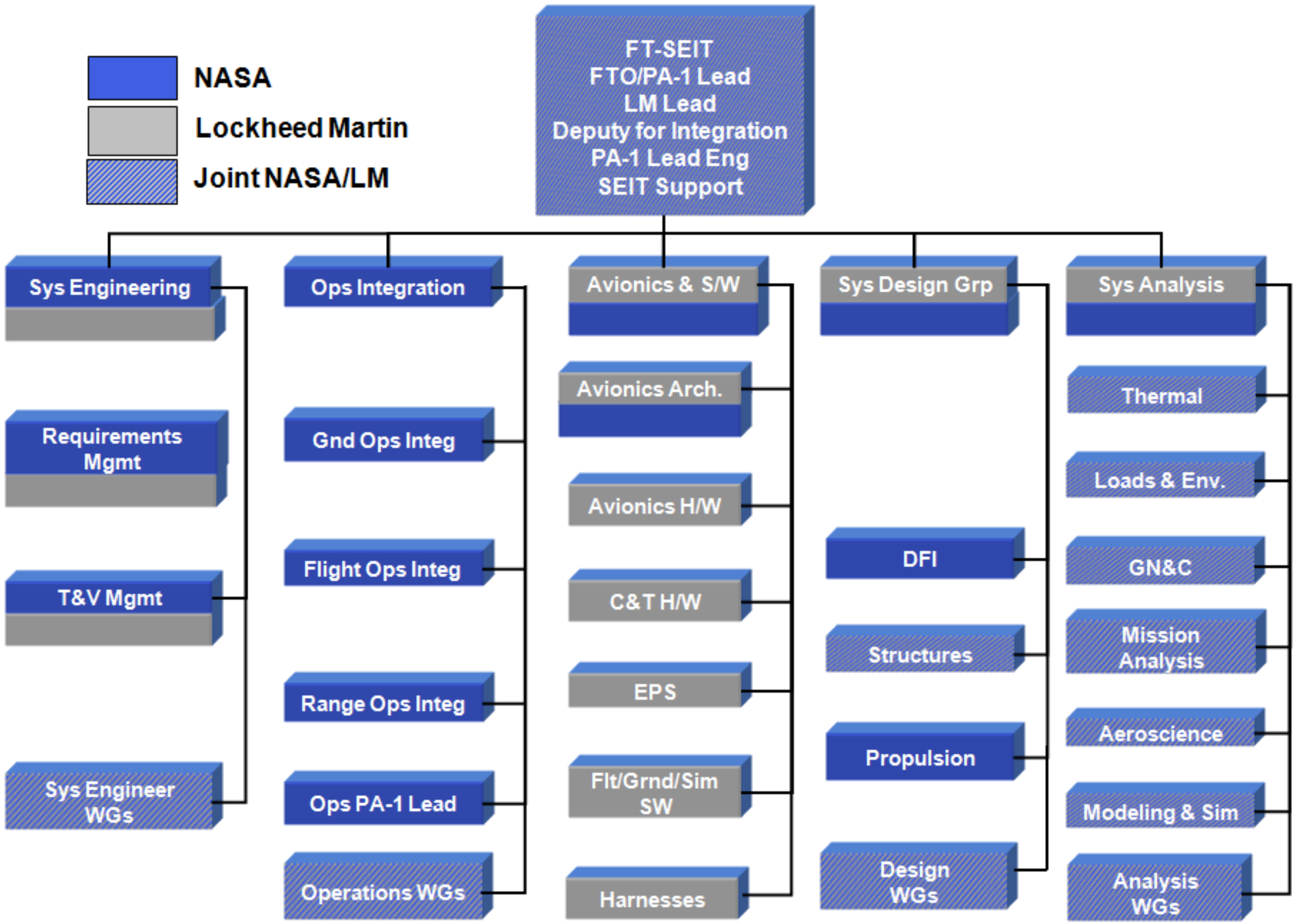
Flight Test Office (FTO) Org. Chart for PA-1

(for reference)



Systems Engineering Integration Team (SEIT) Org. Chart for PA-1

(for reference)



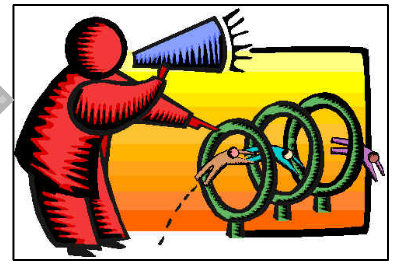
Gathering inputs from <u>ALL</u> the Customer Stakeholders
(What we learned on PA-1)

Need good representation from your primary customer & system stakeholders early in your lifecycle.

- **Besides the primary customer, get inputs from other system stakeholders**
  - Anyone than can drive your system requirements
  - i.e. Orion project, Launch site safety, missile treaties, standards, etc…

Gathering all stakeholders can be more difficult than expected

- NASA stakeholders commonly spread out across multiple centers, agencies & industry partners
- Cross-talk amongst system stakeholders may be hampered
- Need 'community organizer' approach to gather stakeholder inputs early



If Johnny-Come-Lately's join the system stakeholder forum late:

- Risk of adding late driving reqts (additional work & schedule delays)
  - Applies to both baselining project reqts & technical review entrance / exit criteria.
- May induce huge delays (& costs) if late inputs result in modifying a major contract or redesigning.

Finding out what the Customer Needs

(What we learned on PA-1)

Initial draft of Mission / Flight Objectives received from customer *<u>were not</u>* mutually understandable.

- Could have been interpreted differently between the parties (project & customer).

Assumed mutually understandable Mission / Flight Obj. would be delivered the first time on a silver platter *(not the case)*

- Needed to broker some of their Orion production goals into a flight test realm
- Solution: We drafted what 'we' thought their needs were
  - Then asked them to tell us where we were wrong.

Project & customer need to establish a <u>technical rapport</u>

- Was <u>necessarily</u> tedious & difficult to accomplish
- Lowered the risk of unknowingly talking past each other
- Avoided discovering disconnects later in the lifecycle
  - Usually at integration… (too late)

Commonly understood reference point (Little Joe II) was used to directly engage the customer in <u>mutually understandable</u> discussions for Mission / Flight Objectives.

Apollo

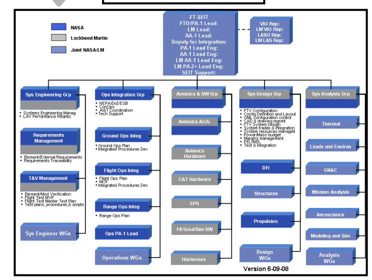
~

Orion

Organizing the Project to… Build the System
(What we learned on PA-1)

Two - Layers to the systems engineering challenge:

1. **Definition, Development, Verification of the system under test**
2. **Definition and structure of the support organizations (the people)**
   - I was taught… The structure of the project needs to reflect your system architecture.
     - Dinesh Verma, Dean School of Systems & Enterprises @ Stevens Inst. Of Tech.
   - Gaps in project structure = gaps in system function & performance.



Expand on Challenge #2: Coordinate different groups at multiple levels across different parts of the country

- Less of a purely technical effort
- More of an Engineering / project-based community organizing effort

Upcoming Slides to address Challenge #2:

- From: Fragmented Organizational-centric (NASA centers & contractors) cultures
- To: Single project-centric culture.
- SE personality type needed to engage communication across project teams
- Organizational structure reflecting the architecture… for PA-1 project

From: Multiple Organizational Cultures
To: Single Project-centric culture

What we learned from PA-1….

Newly defined project roles & responsibilities, processes established across a large (multiple org.) project are not instantaneously carried out in a perfect manner.

It takes some mutual pain (& more time than most like) to transition:

- From: Non-integrated Center & contractor set of cultures, to an…
- To: Integrated project-centric culture.

Need influential advocates (community organizers) from each org working together.

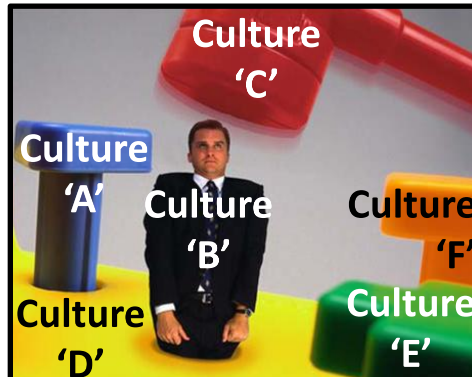
- Key agents from each org advocate project-centric culture, approach, processes back to their group.

Need a comprehensive approach / plan to define / develop / test system as well as structure project.

- Each org buys into.

On PA-1: Became predominantly known as a project-centric culture between PDR & CDR

- Biased opinion of presenter, not scientific assessment



Non-integrated Center & contractor cultures

Integrated project-centric culture

From: Multiple Organizational Cultures
To: Single Project-centric culture

What we learned from PA-1…. (Cont.)

Set up communication forums / hubs for technical cross talk

- Roll call & status from <u>all</u> discipline leads

Need team-wide collaborative web environment

- One place to find the latest document version & related info.
- Very helpful with coordinating & tracking verification
- Sometimes difficult to achieve
    - Organizational web security standards
    - Contractual / proprietary issues among project partners

Project & Team-wide meeting calendars were essential

- One reference point for team meetings.

Team social events away from PowerPoint venues were beneficial

Flight Test Office had direct control over most project teams….

- **But only had 'influence' over some project teams**
    - Could not rely on direct (contractual) authority
    - Rely even more on community organizing skills to engage these groups and… *the mgmt structure above them.*
    - Dedicate person within project to work directly with 'influence-only' partners.

From: Multiple Organizational Cultures
To: Single Project-centric culture

What we learned from PA-1…. (Cont.)

Watch out for the typical engineering drill-down mentality

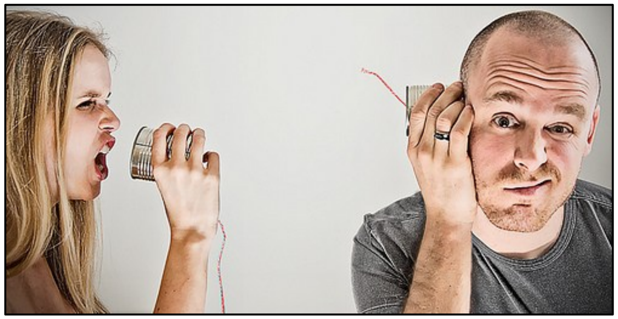
- "I'll focus on my part, you focus on yours…"
- Most engineers delight in avoiding the human interaction aspect of engineering and desire to focus solely on the product itself.
- Reiterate: Engrs. need to think & talk across org. & system boundaries

Project communication gaps swarm around Lone Rangers

- Project Community Organizers need to spot & close these gaps

Assume cross-functional project communication will fail at some point unless:

- Key disciplines across project are proactively & directly engaged regularly… throughout lifecycle
- "Unless everyone who needs to know does know, ... somebody somewhere will foul up"
    - Eberhardt Rechtin, 1997, The Art of System Architecting



From: Multiple Organizational Cultures
To: Single Project-centric culture

What we learned from PA-1…. (Cont.)

Some PA-1 evidence of a project-centric culture:

Unsolicited comment from a Lockheed avionics engineer to a NASA systems engineer (PA-1 post-flight '*social*' event):

- "It would be a shame to break up this team… For example, whenever I wanted, I could just pick up the phone and talk directly to the (LaRC) structures lead to see how possible changes affect us both."

Valuable Systems Engineering traits when Organizing a Project

Systems Engineering / Community Organizer traits:

- **Don't necessarily have to be overly social**
- **However SE'ers need to:**
  - Engage a wide variety of personality types across the project
  - Be very approachable
  - Recognize communication gaps, for example:
    - Only hear repeated concerns on only one side of the story / issue.
    - No clear way for groups to engage each other
  - Carry forward concerns / issues over communication barriers
  - Be organized… beyond just yourself
    - Also be an organizer
  - Participate in regular forums that promote cross-talk
- **Value added if above qualities apply to project leads as well.**
  - Others on the project can help organize, but….
  - It's the SE's job to assure the organizational structure supports the architecture

Valuable Systems Engineering traits when Organizing a Project
(continued)

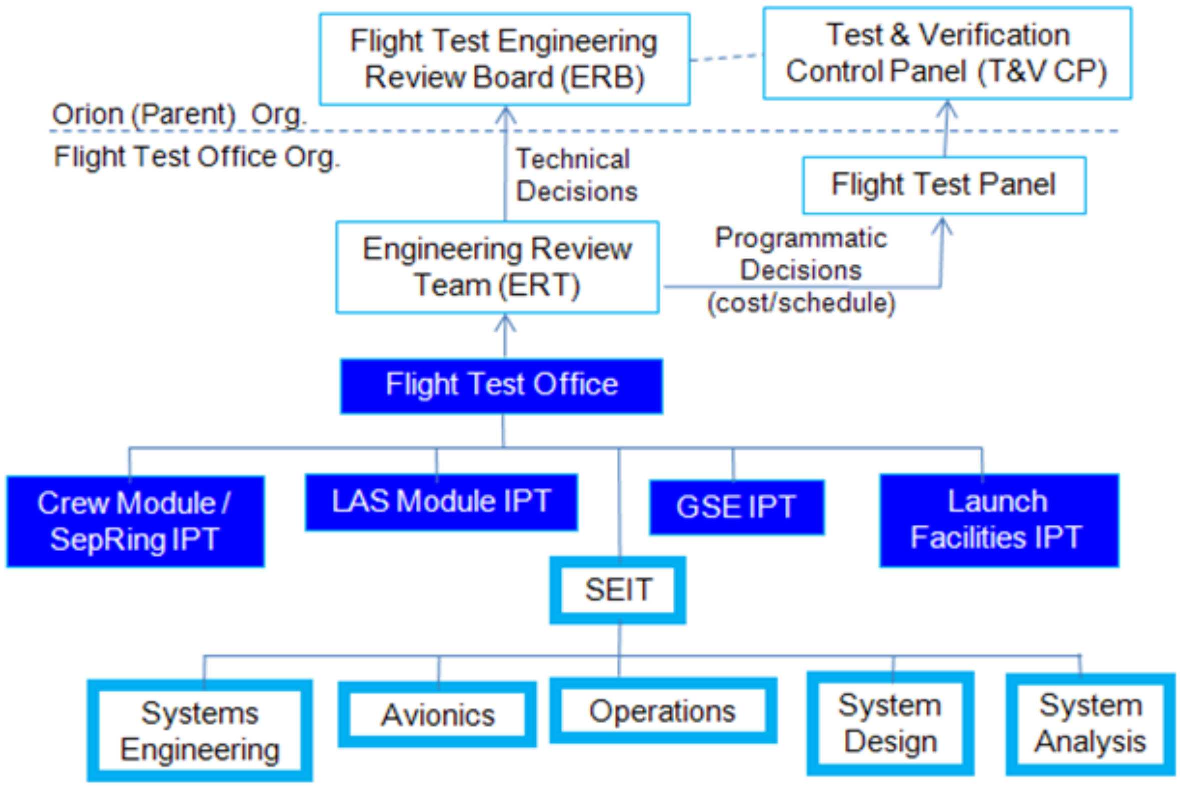
When project leads are not a fan of NPR 7123.1a

- Don't confront them as if you're the NPR police…
- Win them over by asking, "How can we best make '______' clear to others within the project?"
- This is how they can meet the intent of NPR 7123.1a …. w/o them knowing it *(sneaky…)*
- In the background you can check off the NPR 7123.1a check-list

Some project leads may not fully understand Systems Engineering

- Help ghost-write their requirements if necessary
    - This was done for 1 module and 1 subsystem on PA-1

Project structure used to establish project-centric culture (for PA-1)



Positions were discipline & deliverable specific, not center specific.

Can't guarantee this is the best way to organize, but:
- It was clear and understandable to the team… which compensates for a lot.

Parent Org (Orion) Structure:
- **ERB:** Technical decisions impacting parent org
- **T&V Control Panel:** Cost / schedule decisions impacting parent org.

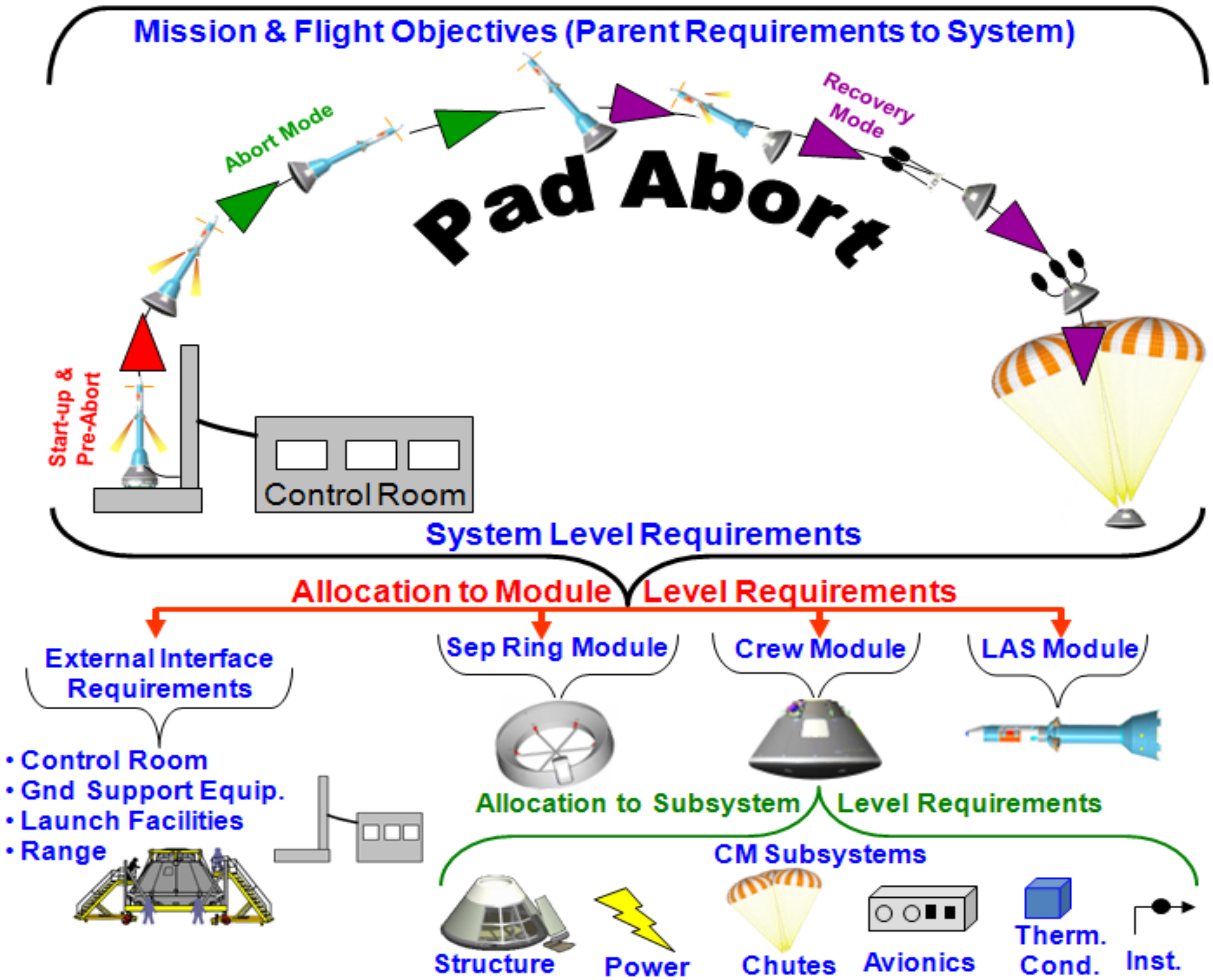
FTO Org. Structure:
- **ERT:** Tech. decisions w/in FTO
- **Flt. Test Panel:** Cost / schedule decisions w/in FTO
- **4 Module level IPT's**
- **SEIT (5 branches)**
  1. Systems Eng.
  2. Avionics (largest & most complex subsystem)
  3. Operations
  4. System Design
  5. System Analysis
  - **Met every week**

Defining the Architecture

- **“If social cooperation is required, the way in which a system is implemented and introduced must be an integral part of its architecture.”**
    - Rechtin, E. “Systems Architecting, Creating & Building Complex Systems”

Defining the Architecture (Cont.)

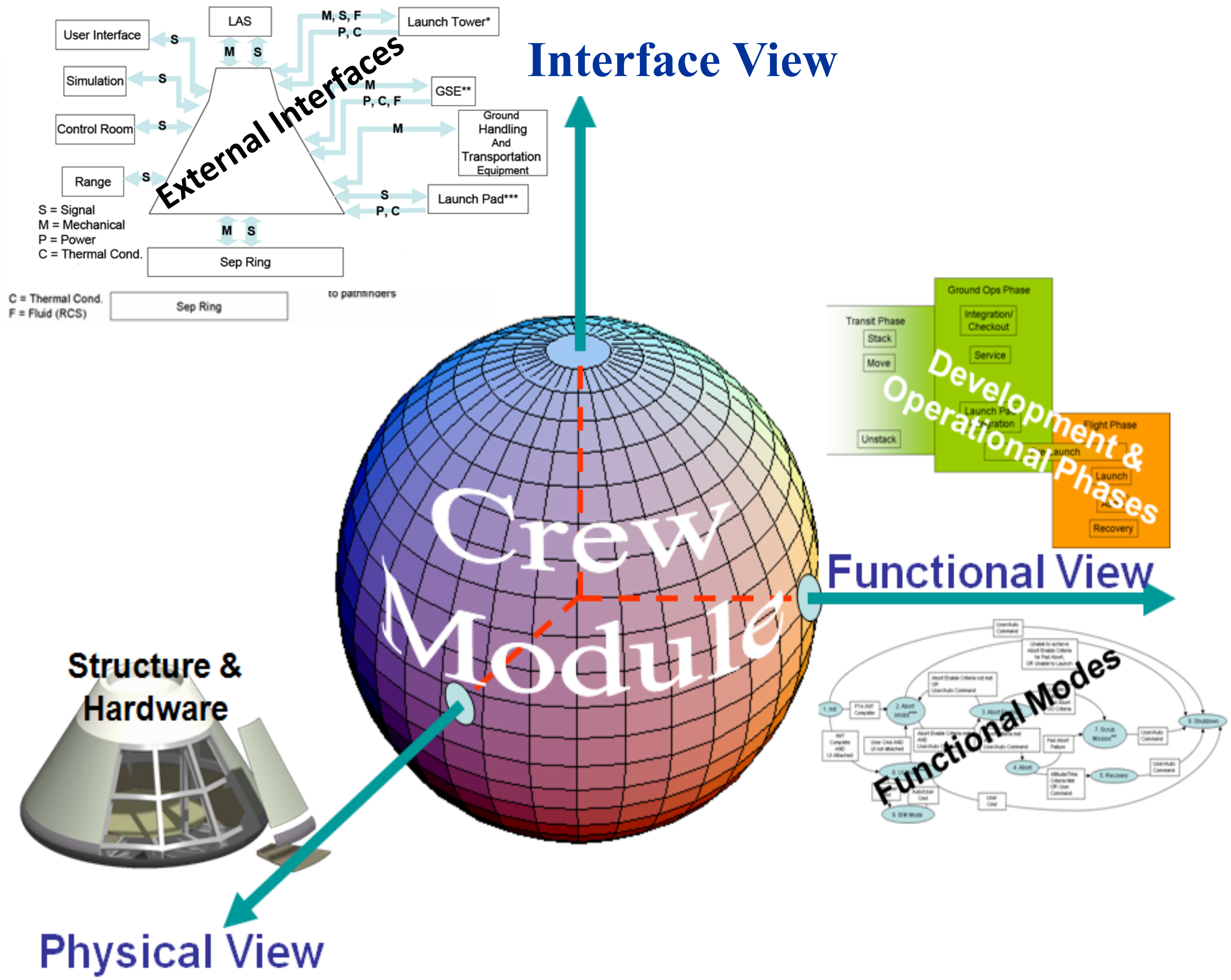
- **Before we generated system requirements, we defined the architecture**



Definition of architecture helped:
- Define spec. tree hierarchy
- Define requirement allocation categories
- Define boundaries of elements within system
- Next slide… looked at system elements from 3-views

Example of 3-View Architecture Definition for Crew Module

(This approach was used across the system)

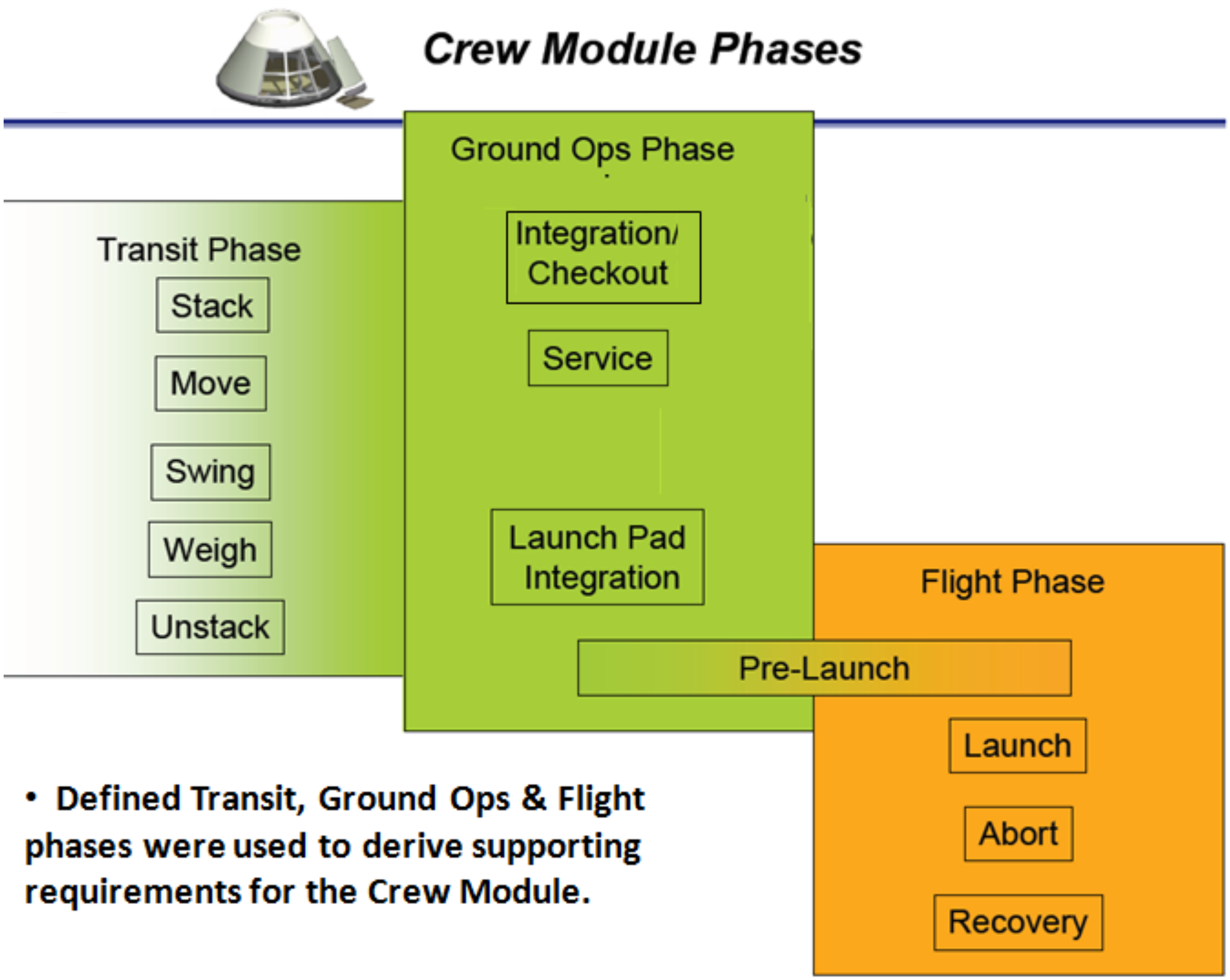


Took global perspective of system elements:

- **Functional View**
  - Dev. & Op. Phases
  - Functional Modes
  - Sample slides shown
- **Interface View**
  - External Interfaces
  - Sample slides shown
- **Physical View**
  - High Level Physical Attributes
  - More detailed attributes (weight, C.G., Moments of Inertia, OML) in a separate Geometry & Mass Properties doc.
  - No sample slide

Actual 'Phase' Chart shown @ PA-1 SRR

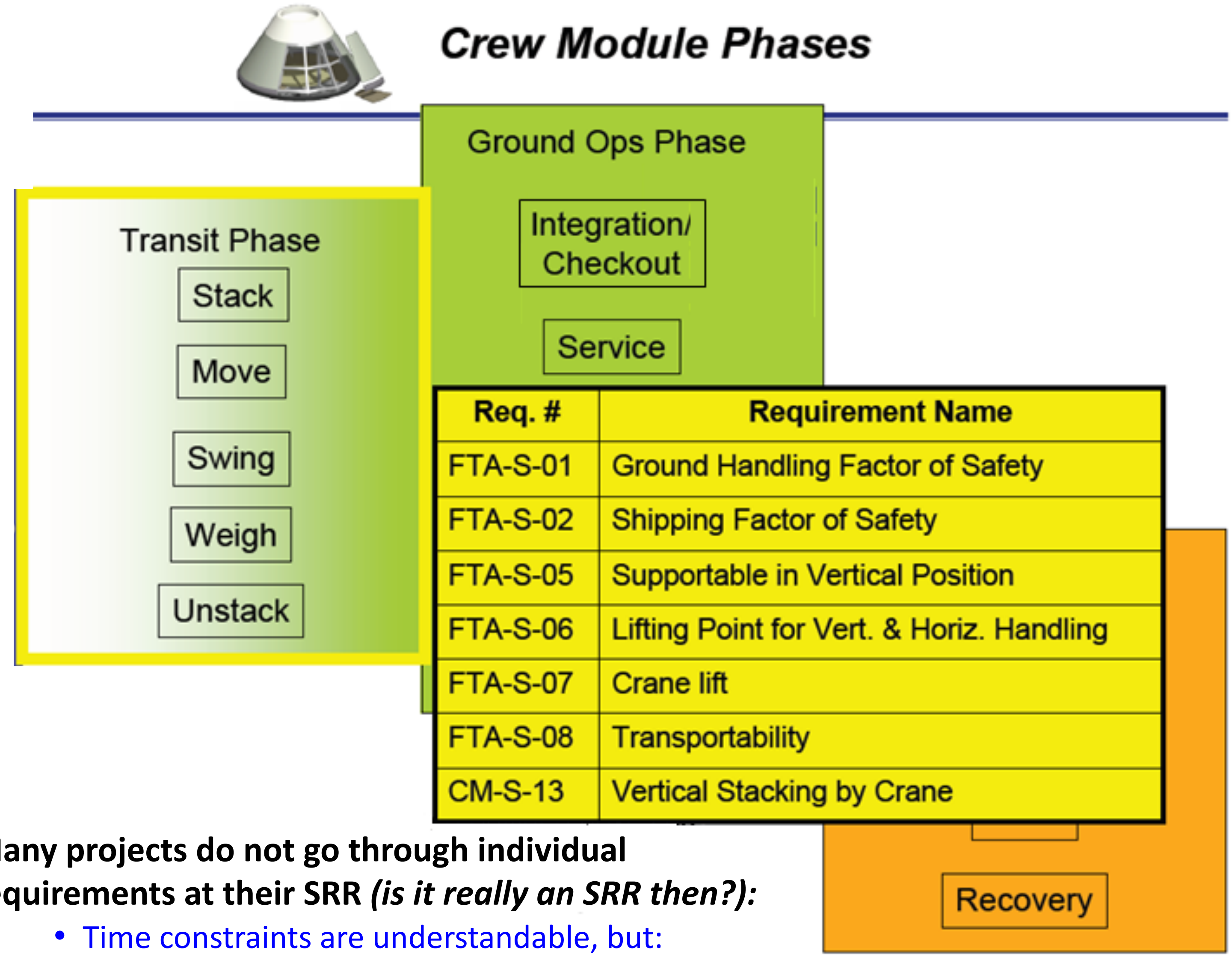
(From Functional View)



- Defined Transit, Ground Ops & Flight phases were used to derive supporting requirements for the Crew Module.

Actual 'Phase' Chart shown @ PA-1 SRR (Cont.)

(From Functional View)



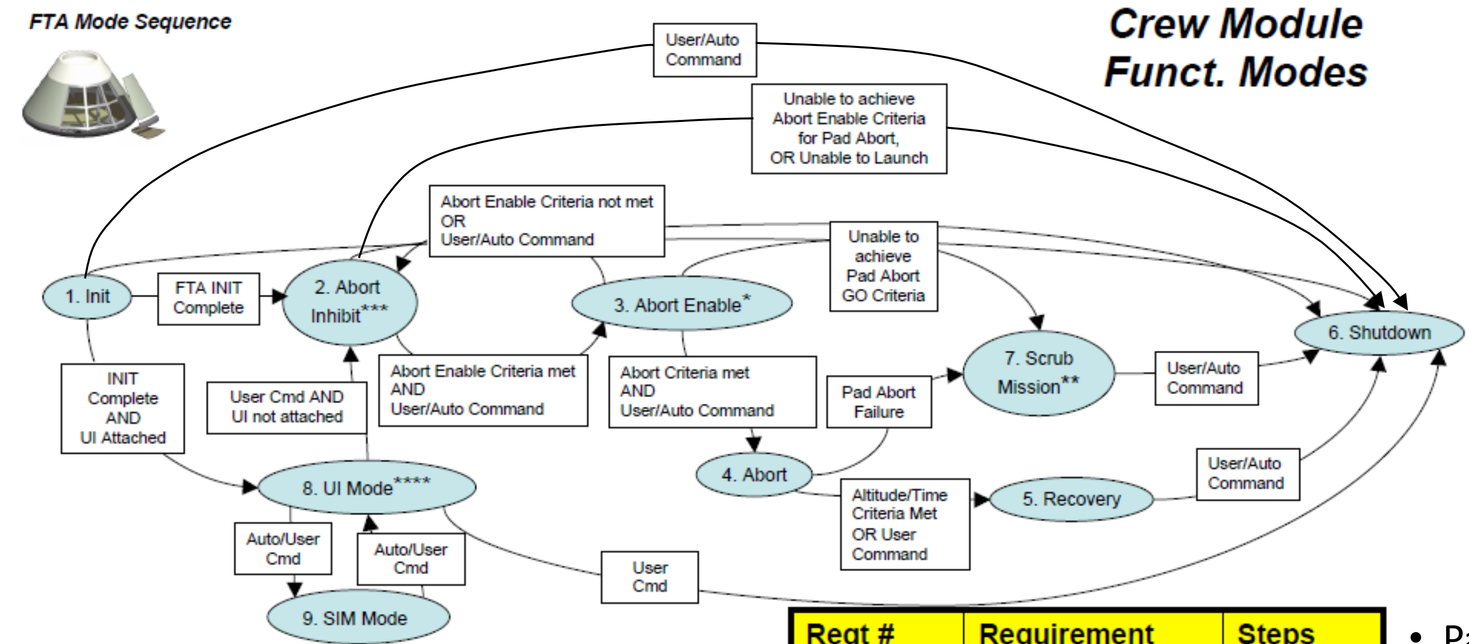
Req. #	Requirement Name
FTA-S-01	Ground Handling Factor of Safety
FTA-S-02	Shipping Factor of Safety
FTA-S-05	Supportable in Vertical Position
FTA-S-06	Lifting Point for Vert. & Horiz. Handling
FTA-S-07	Crane lift
FTA-S-08	Transportability
CM-S-13	Vertical Stacking by Crane

Many projects do not go through individual requirements at their SRR *(is it really an SRR then?)*:

- Time constraints are understandable, but:
- Example above is proof it's possible to review requirements at a 'paraphrased' level at SRR.

Actual 'Functional Mode' Chart shown @ PA-1 SRR

(From Functional View)



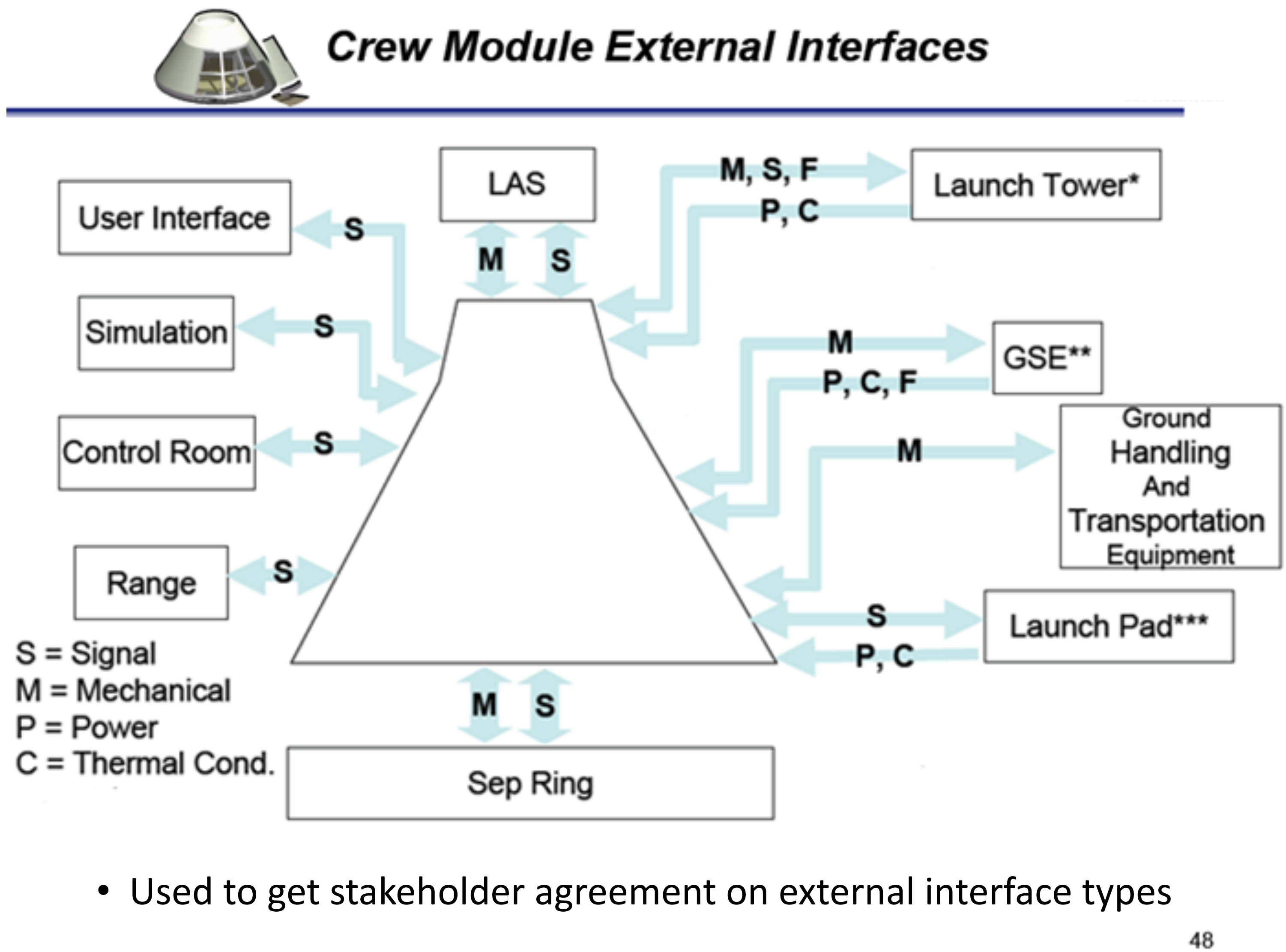
Reqt #	Requirement	Steps
FTA-F-07	Startup	1
FTA-F-24	Init to IU	1 to 8
FTA-F-08	Abort Inhibit	2
FTA-F-09	Init to Abort Inhibit	1 to 2
FTA-F-10	AI to AE	2 to 3
FTA-F-11	AE to AI	3 to 2
FTA-F-12	AI to Shutdown	2 to 6
FTA-F-13	Failed Launch SD	2 to 6

Reqt #	Requirement	Steps
FTA-F-02	Abort	3 to 4
FTA-F-14	Failed Abort SD	3 to 7 to 6 4 to 7 to 6
FTA-F-03	Recovery	4 to 5
FTA-F-15	Shutdown	5 to 6
FTA-F-23	Init to SD	1 to 6
FTA-F-25	UI to SD	8 to 6
FTA-F-28	UI to Sim	8 to 9
FTA-F-26	Sim to UI	9 to 8
FTA-F-29	UI to AI	8 to 2

- Paraphrased versions of the requirements were used to walk reviewers thru the requirements at SRR in an expedient manner.

Actual 'External Interface' Chart shown @ PA-1 SRR

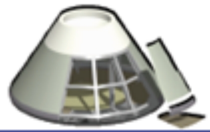
(From Interface View)



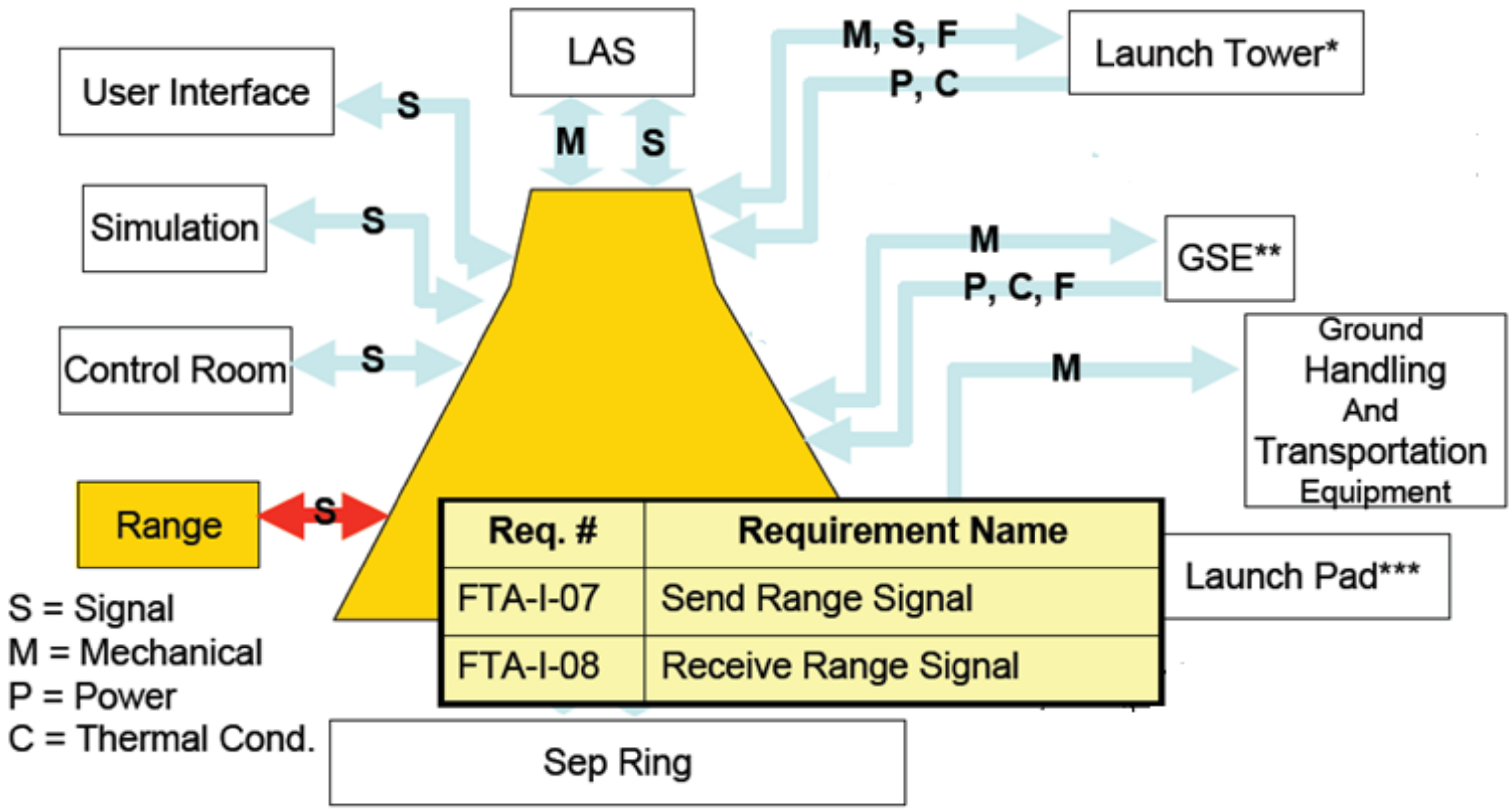
- Used to get stakeholder agreement on external interface types

Actual ‘External Interface’ Chart shown @ PA-1 SRR (Cont.)

(From Interface View)



Crew Module - Range Interface

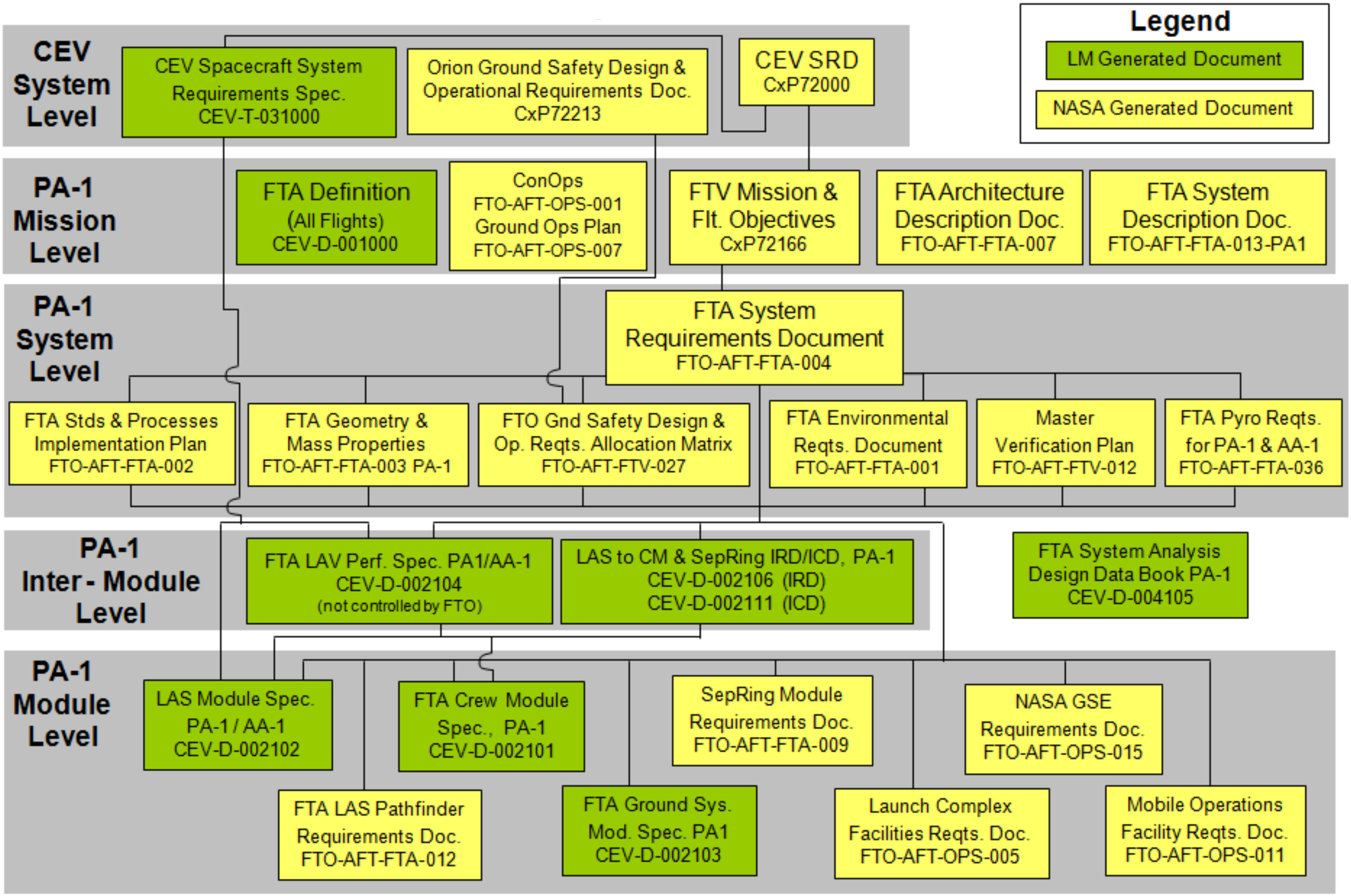


Req. #	Requirement Name
FTA-I-07	Send Range Signal
FTA-I-08	Receive Range Signal

- Paraphrased versions of the requirements were used to walk reviewers thru the requirements at SRR in an expedient manner.

Top Tier of PA-1 Spec Tree

(For Reference)



Defined System & Instrumentation Sensors in a parallel manner

Mission Objectives drove the system-wide design

Flight Objectives Drove Master Measurement List for the sensors

Mission Objective: … demonstrate satisfactory perf. & operation of the LAS.

Mission & Flight Objectives

Fl[illegible] Objective: Determine stability char. of LAS+CM configuration during a pad abort

Standard allocation to lower level requirements

System Requirements Document

Module A

Module B

Module C

Subsystem A

Subsystem B

Subsystem C

Data Analysis Plan

- **Measure Of Performance (MOP):**
  - Evaluate LAV attitude (including flight path angle, ψ, θ, ϕ)
- **Evaluation Criteria:**
  - LAV dynamics compared to 6-DOF simulation, adjusting for day-of-flight conditions
- **Required Parameters:**
  - LAV position, velocity, acceleration, attitude, angular rates, angle of attack, sideslip, estimated thrust from abort motor, day-of-flight winds, and atmospheric conditions derived from on-board measurements.

Master Measurement List (MML)

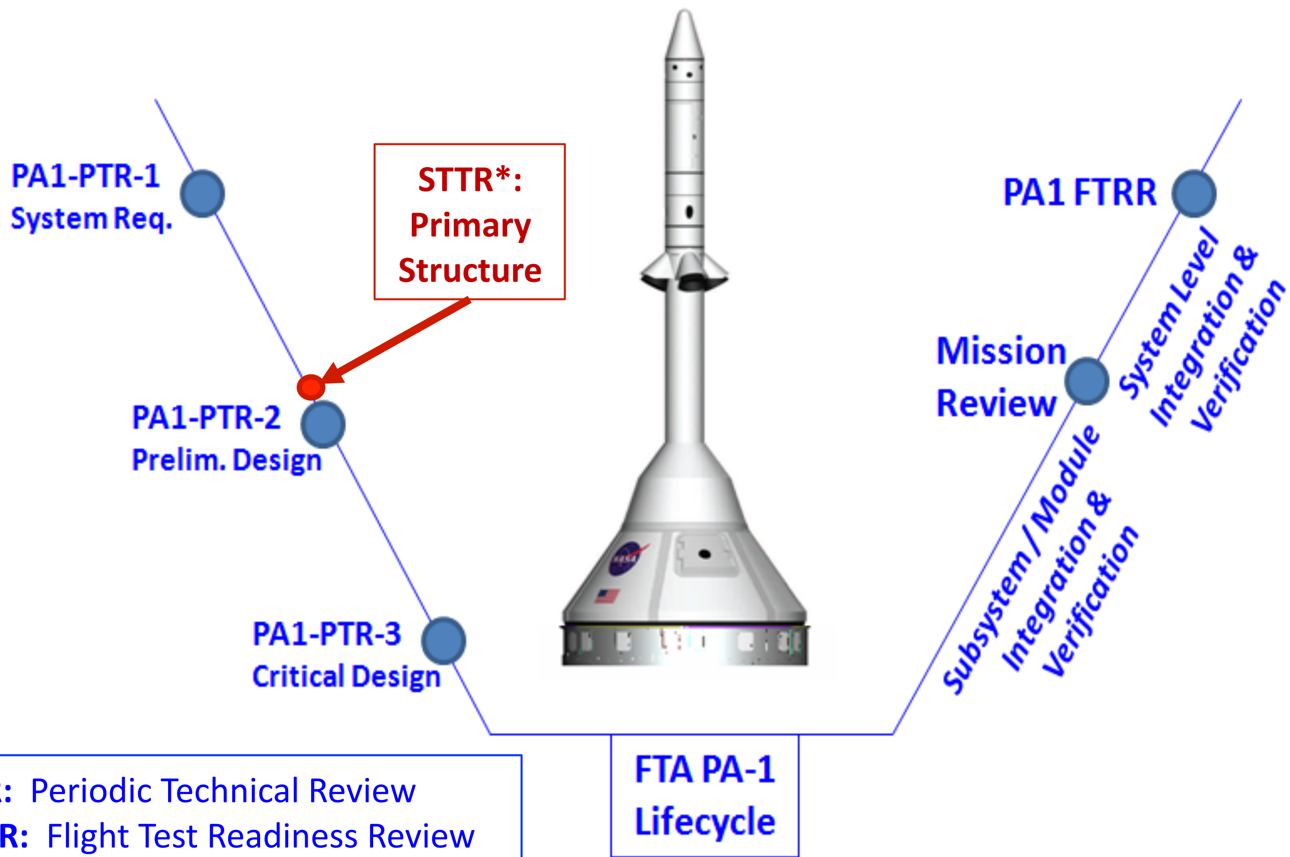
- **LS041V: Z-axis acceleration ….**
- **LS0….**

Pad Abort 1 Review Lifecycle

- "Before proceeding too far, pause & reflect! Cool off periodically and seek an independent review"
    - Douglas R. King, 1991

- "If you think your design is perfect, it's only because you haven't shown it to someone else."
    - Harry Hillaker, 1993

Pad Abort 1 Review Lifecycle (Cont.)



PTR: Periodic Technical Review
FTTR: Flight Test Readiness Review
STTR: Subsystem Table Top Review
*: Discussed further on next page

Pad Abort 1 Review Lifecycle (Cont.)
(What we learned on PA-1)

Technical Review Entrance / Exit criteria tailored from NPR 7123.1a Appendix G

- Approved by customer well before each review
- Resulted in mutually clear expectations for each review early-on

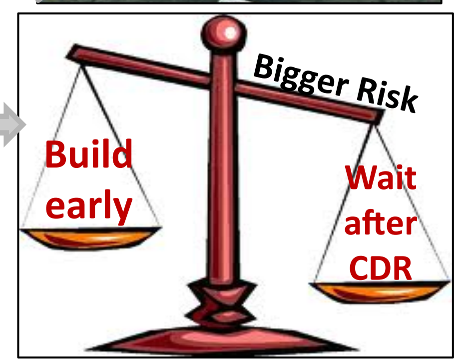
Early coordination with customer helped achieved timely buy-off of review approach

- Increased likelihood of reviews meeting customer expectations
- Without early coordination: Increase risk of surprising customers at the review *("… can't proceed to the next phase until…. you do A, B, C, etc…")*

- **WARNING: Customer may still change their mind on review criteria**
  - But, baseline criteria will help justify impacts

STTR approach used to approve procurement & basic design of CM Primary Structure before PDR (yes, I said PDR).

- **Used only if:**
  - Risk of expediting project is lower than the schedule risk of waiting for the review
  - Have a well established risk mgmt system to track / update risk mitigations (i.e. workable retro-fits for increased loads from downstream analysis).



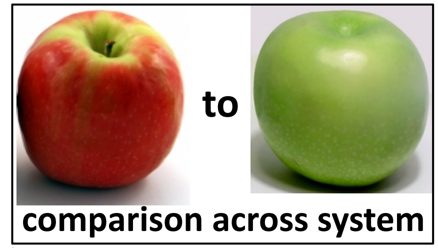
Risk scale

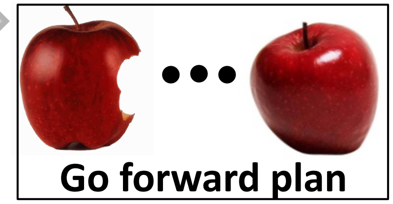
Pad Abort 1 Review Lifecycle (Cont.)

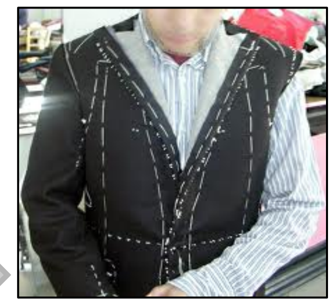
(What we learned on PA-1)

Entrance / Exit criteria used to define presentation template for each subsystem at each technical review.

- Provided <u>consistency</u> for each subsystem presentation
- Made it easier to define subsystem readiness <u>gaps</u> (issues) & go fwd plans
- Reduces chance of <u>overlooking</u> something important across system







Tailoring of entrance / exit criteria was / is key:

- I was taught… Strictly following a text book approach for systems engineering on a project would practically <u>guarantee failure</u>.
  - Dinesh Verma, Dean School of Systems & Enterprises @ Stevens Inst. Of Tech
- Do NOT deny engineering judgment from past pain

Examples of 'tailored' subsystem presentation templates shown on next 2 slides for PDR.

Example of Subsystem presentation outline / template for PDR (PTR-2)

- **Entrance Criteria** – tailored from NPR 7123.1a for your subsystem
- **Schedule** – Subset of the master schedule for your particular subsystem / deliverables
- **Document/s Status** – Self explanatory
- **Driving Requirements** – Shows requirements that are causing your design to be 'what it is.'
- **Safety** – Hazards pertaining to your particular subsystem
- **External Interfaces** – Summary of interfaces external to your subsystem
- **Design Concept** – Block diagrams, Sketches, Drawing trees, Analysis
- **T&V Approach** – Basic description of Test approach and how requirements will be verified.
- **Issues & Resolutions** – Identify open issues and a plan on how they will be resolved.
- **Go Forward Plan** – Path to CDR
- **Exit Criteria** – tailored from NPR 7123.1a for your subsystem

- Resulted in reviewers knowing expected topics for each subsystem.
- Enabled reviewers to consistently compare subsystem readiness across the system.
- Made it easier for project to pro-actively define go-forward plans for subsystem 'issues'

Example of Subsystem Entrance / Exit Criteria template for PDR (PTR-2)

PTR-2 Subsystem Level Entry Criteria	Slide
Preliminary subsystem specs for each H/W & S/W CI	
Draft Subsystem Interface Requirements Docs	
Draft Interface Control Documents	
Design / Analysis Documentation	
Engineering Drawing Trees	
T&V Planning	

- Consistently showed reviewers 'how' each subsystem met its share of the system-wide entrance / exit criteria.
- If template not used… could result in inconsistent coverage from subsystem to subsystem.
    - Reviewers may conclude project coordination is inconsistent
    - Warning flags go up

PTR-2 Subsystem Exit Criteria	Evidence	Slide
Subsystem requirements defined & trace to parents & are allocated to components & external subsystems	• Driving Requirements show traceability • Requirement allocations are in specs	
Subsystem Level designs exist and are consistent with their corresponding requirements set	• Design spec complete with ___ TBD/Rs • Design drawings ___% complete	
Subsystem interfaces identified and are consistent with their corresponding subsystem design maturity	• IRD / ICD's with ___ TBDs / TBRs	
Project risks identified & mitigation strategies defined	Project risk #'s in IRMA risk database	
T&V approach is adequate to proceed	Verification methods identified & test	
S&MA adequately addressed in the preliminary design & the preliminary design-based S&MA requirements & approach have been approved	Hazard report #'s & referenced S&MA analysis	

Verification

(What we learned from PA-1)

Early-on:

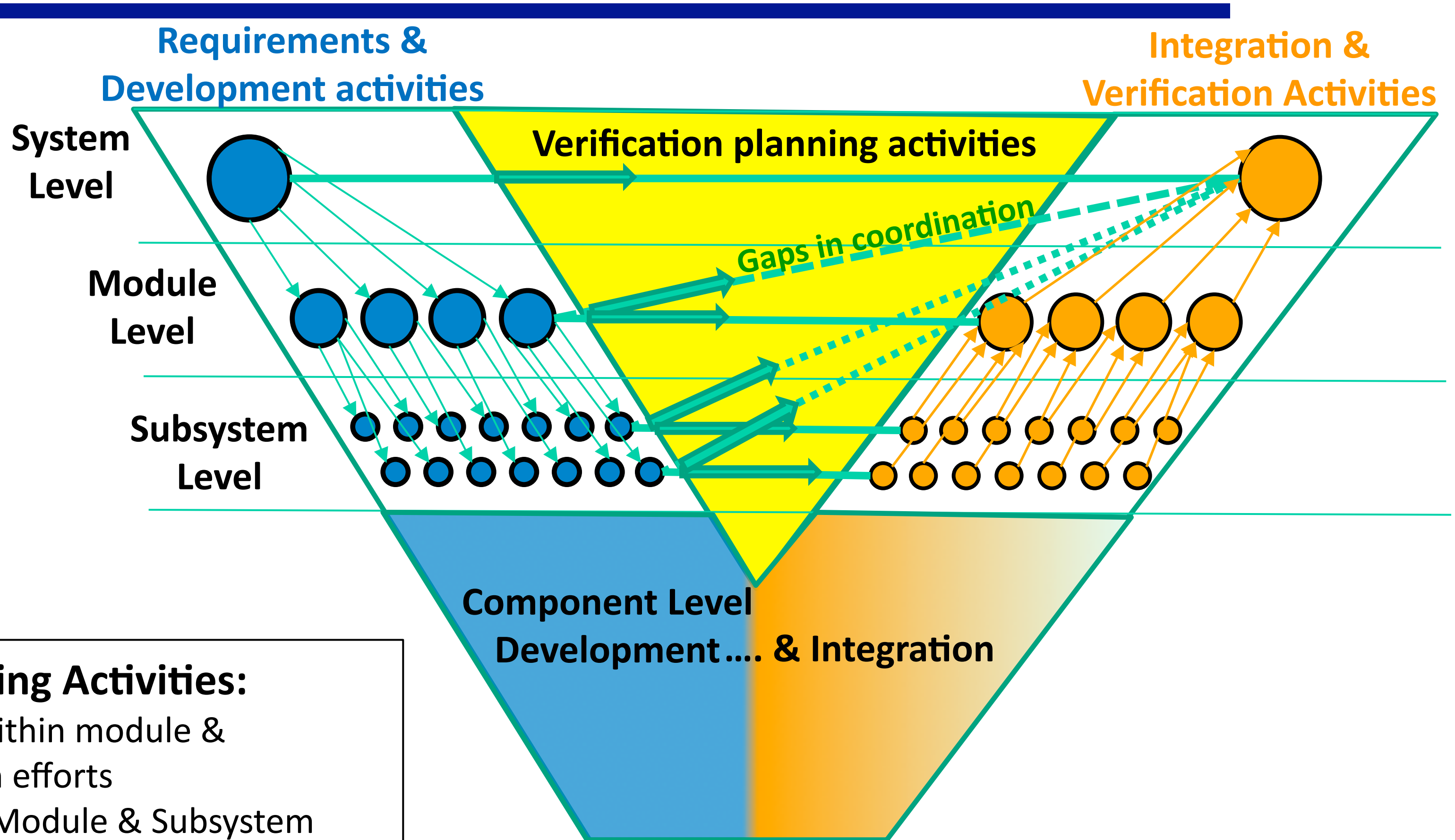
- Believed defining & implementing workable requirements would be the greater challenge
- Foregone conclusion that the easier task would be to record the verification of those same requirements later in the lifecycle. **(WRONG)**

Looking-back:

- **Experience taught us:**
  - No tasks can realistically be categorized as significantly easier through lifecycle
  - Complexity of coordinating the human element of requirements verification comparable to human element challenge of implementing those same requirements earlier in the lifecycle.
    - i.e. Coordinating latest versions of test results & analysis at each associated level while briefing burn-down status
      - Next slide touches on contributors to this challenge

Verification Planning

(What we learned from PA-1)



Verification Planning Activities:

- Strong correlation within module & subsystem verification efforts
- Gaps in correlating Module & Subsystem verifications with System level verif. activities
  - Leads busy implementing requirements & design early in lifecycle
  - Less time to tie all levels in system verification planning
  - Made for more work later in the lifecycle to correlate latest (under the gun).

Lesson Learned:

- Where ever possible: Complete system verification planning efforts with module & subsystem leads earlier in the lifecycle
  - Set up more direct 'check-list' of tasks to reduce avoidable system-wide review & analysis later in the lifecycle

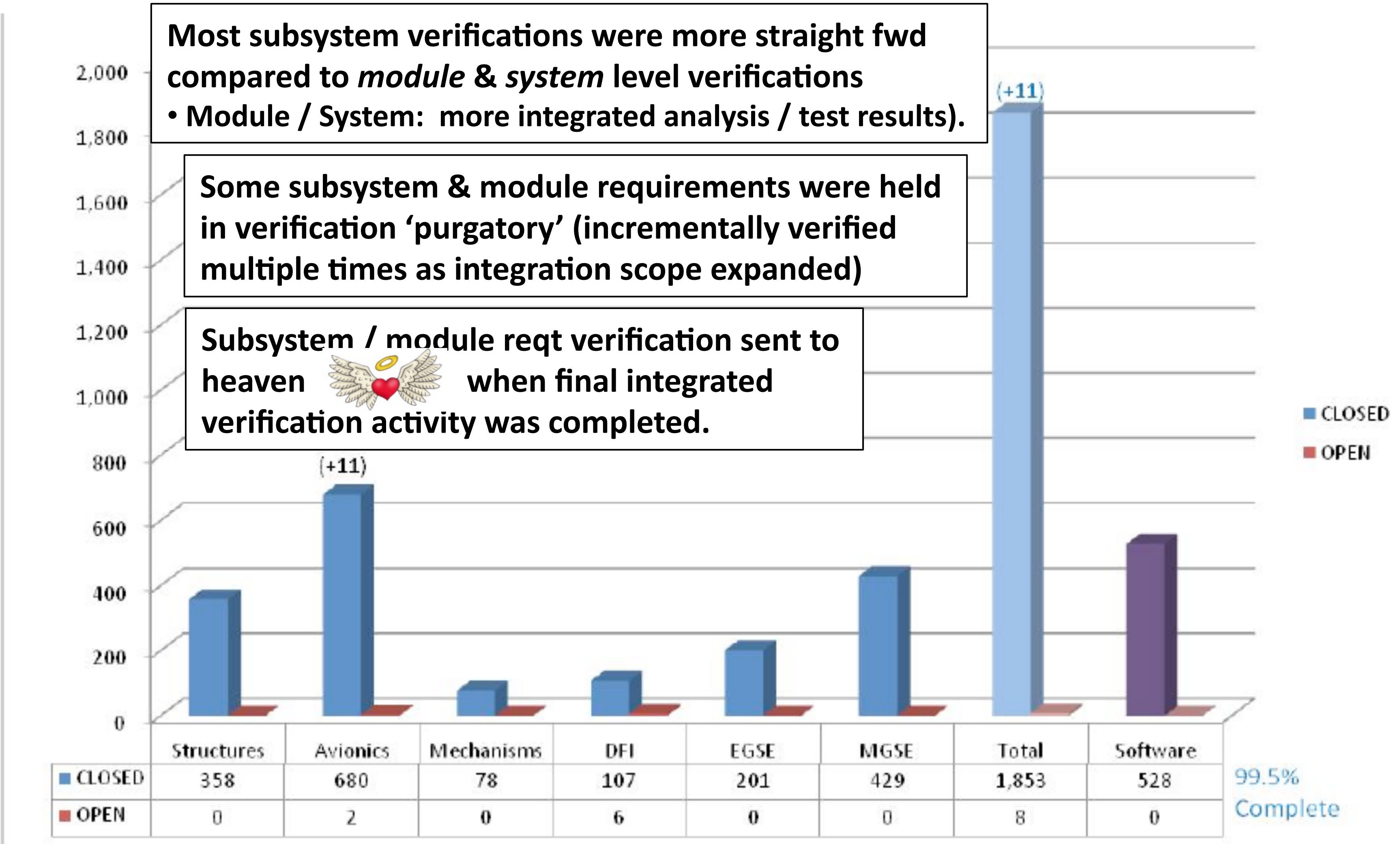
Actual PA-1 Subsystem Verification Chart briefed to Mgmt.

What we learned from PA-1…

Most subsystem verifications were more straight fwd compared to *module* & *system* level verifications
- **Module / System: more integrated analysis / test results).**

Some subsystem & module requirements were held in verification 'purgatory' (incrementally verified multiple times as integration scope expanded)

Subsystem / module reqt verification sent to heaven when final integrated verification activity was completed.



	Structures	Avionics	Mechanisms	DFI	EGSE	MGSE	Total	Software
CLOSED	358	680	78	107	201	429	1,853	528
OPEN	0	2	0	6	0	0	8	0

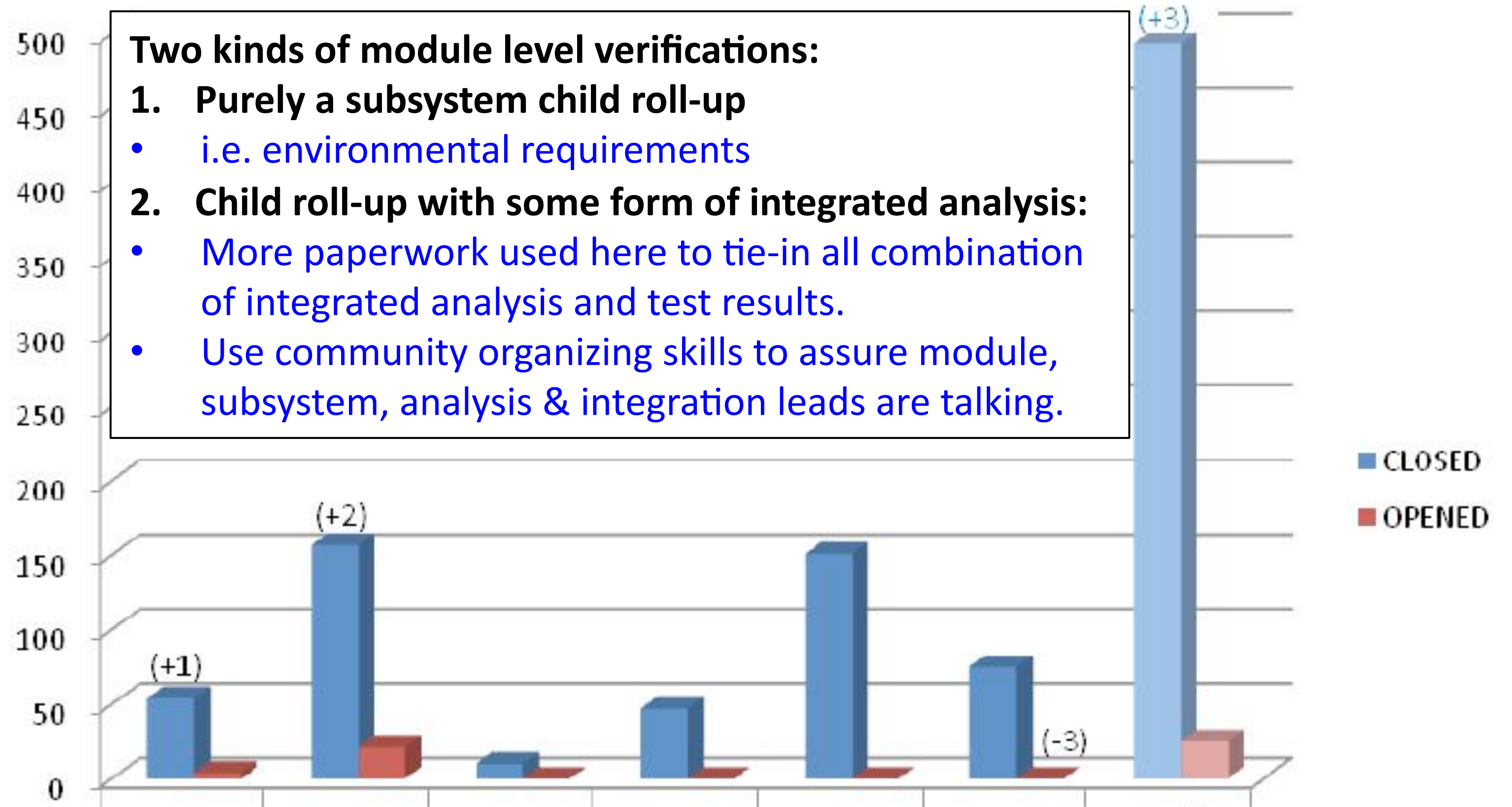
129 subsystem requirements have been closed since January

Actual PA-1 Module Level Verification Status Chart briefed to Mgmt.

What we learned from PA-1…

Two kinds of module level verifications:

1. **Purely a subsystem child roll-up**
   - i.e. environmental requirements
2. **Child roll-up with some form of integrated analysis:**
   - More paperwork used here to tie-in all combination of integrated analysis and test results.
   - Use community organizing skills to assure module, subsystem, analysis & integration leads are talking.



	LAS-CM Interface	CM	CM-SR Interface	NASA GSE	LM GSE	MOF	Total
CLOSED	54	157	10	47	151	75	494
OPENED	4	21	0	0	0	0	25

95 % Complete (+1%)

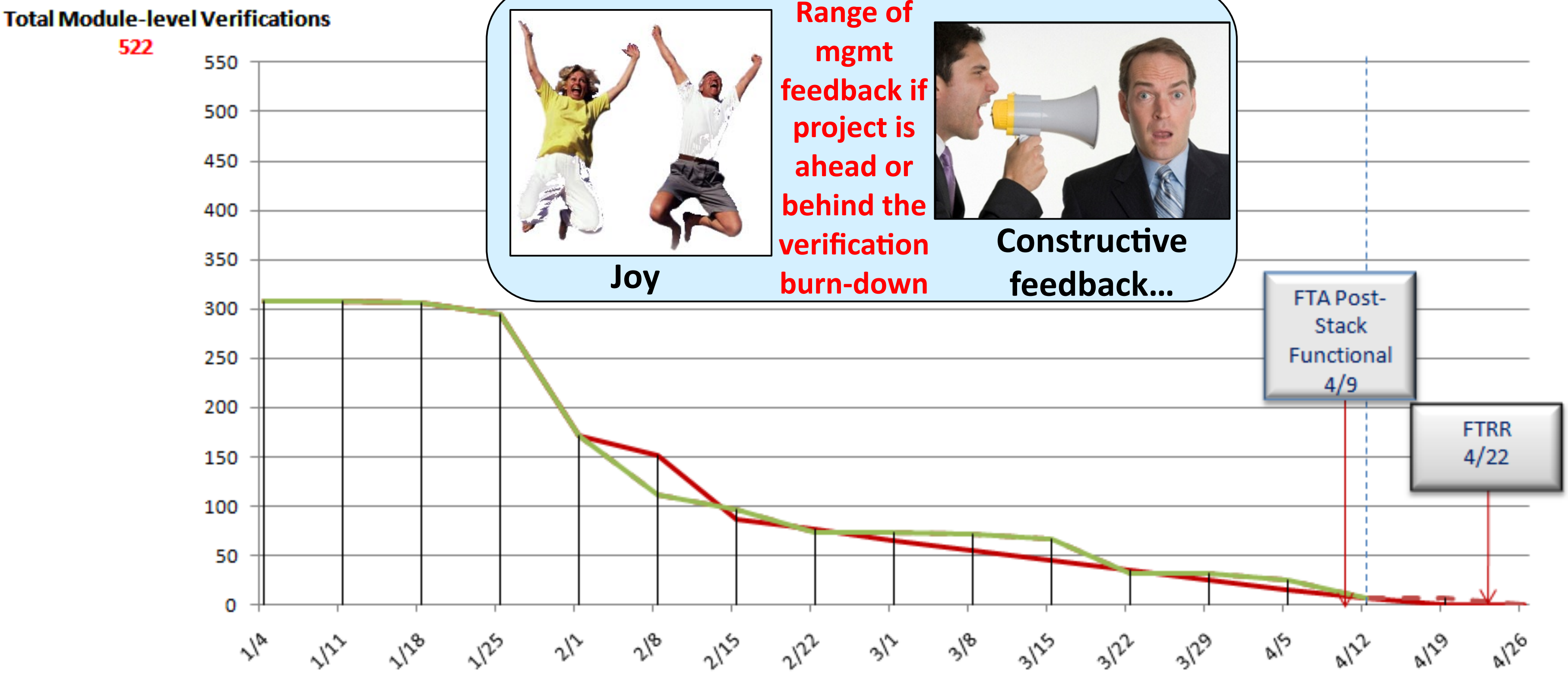
Actual Module Reqts. Burn-down Chart Briefed to Mgmt.

What we learned from PA-1…

Joy

Range of mgmt feedback if project is ahead or behind the verification burn-down

Constructive feedback…



	1/4	1/11	1/18	1/25	2/1	2/8	2/15	2/22	3/1	3/8	3/15	3/22	3/29	4/5	4/12	4/19	4/26
Verifications Plan	308	308	306	294	172	152	87	76	65	55	45	35	25	15	7	0	0
Verifications Projected	308	308	306	294	172	111	97	74	73	71	66	31	31	25	7	6	0
Verifications Actual	308	308	306	294	172	111	97	74	73	71	66	31	31	25	7		

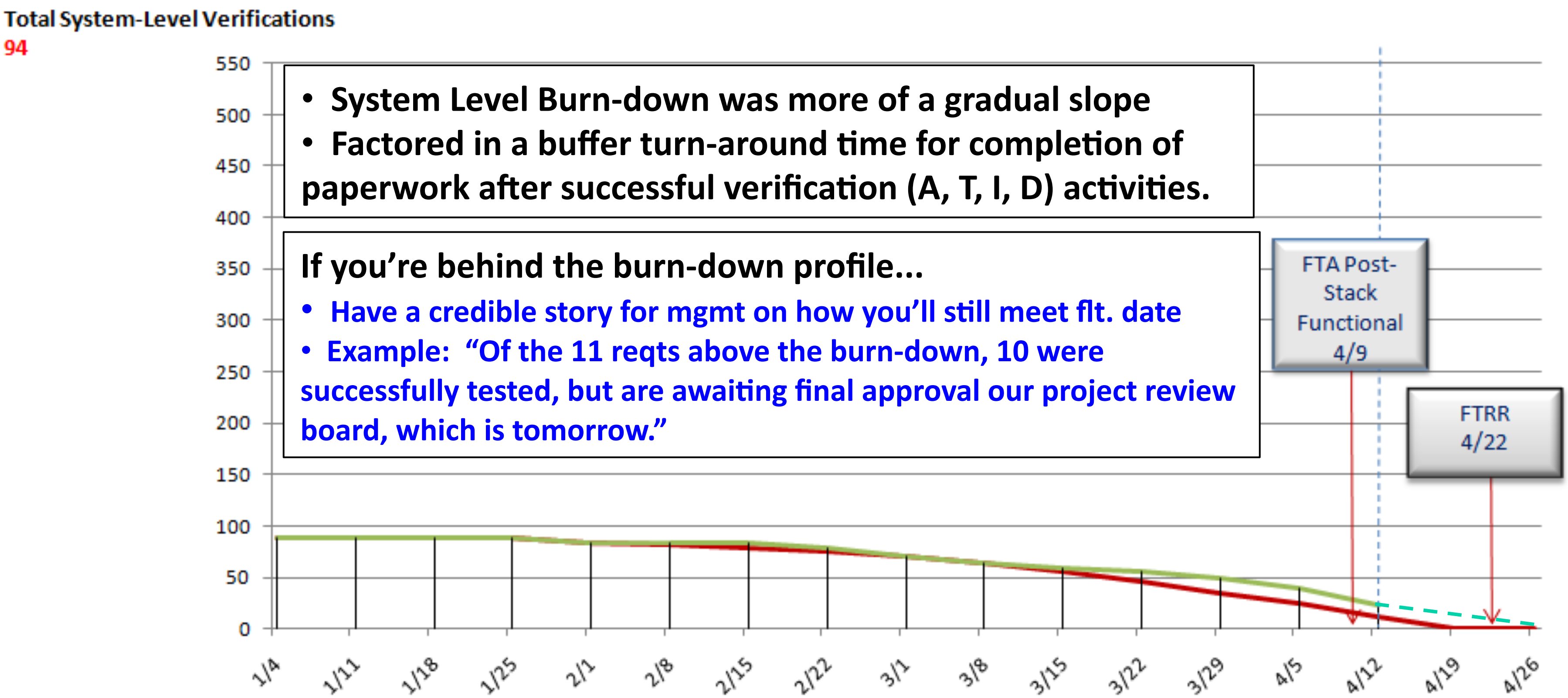
7 unverified requirements
- **6 to close after FTRR (waiting on future activities)**

Actual System Reqts Verification Burndown briefed to Mgmt.

- System Level Burn-down was more of a gradual slope
- Factored in a buffer turn-around time for completion of paperwork after successful verification (A, T, I, D) activities.

If you're behind the burn-down profile...

- Have a credible story for mgmt on how you'll still meet flt. date
- Example: "Of the 11 reqts above the burn-down, 10 were successfully tested, but are awaiting final approval our project review board, which is tomorrow."



	1/4	1/11	1/18	1/25	2/1	2/8	2/15	2/22	3/1	3/8	3/15	3/22	3/29	4/5	4/12	4/19	4/26
System Reqt Plan	88	88	88	88	84	82	79	75	70	64	56	46	35	24	12	0	0
System Reqt Actual	88	88	88	88	84	83	83	79	70	64	59	56	49	39	23		

Conclusions & Perspectives Gained

- Get engaged early with ALL of your parent stakeholders – Establish technical rapport
- Importance of looking at organic parts of the project supporting the system.
    - i.e. Project organization, processes, various disciplines, human nature
    - Needs to be worked in parallel with defining the system
    - Reflects the architecture

- The more clear things can be made within the team, the more achievable a project-centric culture will be.
    - Single reference points for (defined preferably in a collaborative web environment):
        - Project & Team meetings (with charters)
        - Technical & Project decision process - For decisions affecting project or technical baselines
        - Schedule
        - Organizational structure & roles / responsibilities
        - Risk Mgmt
        - Configuration Mgmt
        - Problem reporting & resolution
        - Technical Review approach & entrance / exit criteria
        - Key project & engineering documents
        - Verification Planning

- To get a large group of individuals in different orgs across the country to develop a cohesive system…
    - Takes more than a sound SE approach
    - It also requires a human interaction mindset that is not intuitive to most engineers.

Conclusions & Perspectives Gained (cont.)

- Get stakeholder buy-in of architecture definition before deriving system requirements
  - Derive system requirements from architecture definition.

- Have a template for subsystem presenters at technical reviews tailored from NPR 7123.1a entrance / exit criteria

- Verification coordination will sneak up on you if not thoroughly completed early-on
  - Correlate Module & Subsystem verifications with System level verification activities early-on
    - Reduces frantic scrambling around later in the lifecycle

Side Notes:

- PA-1 project passed 2010 NASA OCE Systems Engineering audit
- 2011 NASA Systems Engineering (SE) Excellence awarded to the Orion Pad Abort-1 SE Team

Conclusions & Perspectives Gained (Cont.)

Systems Engineer Triangle

Knowledge of core SE basics
(define & test system thru lifecycle)

First hand experience in the field
(used for tailoring)

Invaluable Systems Engineer Skill-set

Community Organizer Mindset
(Assure org reflects the architecture)


Questions ???