“Finding NIMA” – An overview of the NASA Integrated Model-Centric Architecture project (and related initiatives)

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GSFC Code 592
Systems Engineering Seminar
August 7, 2012

Credits

- With special thanks to the following for huge chunks of the presentation material:
  - Linda Bromley (JSC, NIMA project lead)
  - Sandy Friedenthal (INCOSE)
  - Russell Peak (Georgia Tech)
  - Dirk Zwemer, Manas Bajaj (InterCAX, LLC)
  - Steve Jenkins, Dan Dvorak, et. al. (JPL)

Presentation Outline

- NIMA at-a-glance
- Needs/Goals/Objectives
- Model-Centric Engineering
- Communities of Practice: M&S, CAD, PDLM, MBSE
- Work to-date: Work Packages, ConOps
- Current Status: Benchmarking, Pilots
- Future Plans
- Related Initiatives
- Summary
- Backup

NIMA at-a-glance

- The NIMA activity was started in June 2011
- Funded by OCE, for balance of FY11 plus FY12-FY14, roughly 8 FTE/year (TBD)
- It is primarily the integration and expansion of the work already being performed separately, in support of all NASA missions, by the following Communities of Practice (CoP):
  - Model-Based Systems Engineering (MBSE)
  - Product Data and Lifecycle Management (PDLM)
  - Computer Aided Design (CAD)
  - Models and Simulation (M&S)
- NIMA was created to coordinate and enhance this work in a more effective way, learning and leveraging off each others discoveries and insights, driving the agency toward a model-centric engineering approach

Finding NIMA Online

- Start with NEN (NASA Engineering Network) located at https://nen.nasa.gov/nen/web/
- Go to Communities and select Systems Engineering (direct link: https://nen.nasa.gov/web/se)
- Go to the Integrated Model-Centric Architecture (under SE Sub-Communities) to get to NIMA (direct link: https://nen.nasa.gov/web/se/nima)
- MBSE is another one of the SE sub-communities (direct link: https://nen.nasa.gov/web/se/mbse)
- PDLM is one of the main NEN communities (direct link: https://nen.nasa.gov/web/pdlm)
- Also, you can subscribe to groups such as MBSE and M&S that are available via Yammer. Go to www.yammer.com and sign in using your NASA e-mail address, then install the client, edit your profile, subscribe to groups, etc.

Needs, Goals and Objectives

Problem Statement

- Looking at our past experiences at NASA, our technical, cost and schedule performance needs to be enhanced in order to accomplish our future plans
- *Some* of the problems to be solved are:
  - Lack of *affordability* of projects and activities
  - Mission *complexity* is growing faster than our ability to manage it
  - Not identifying design or integration *problems* until *late* in lifecycle
  - Having to *hunt* for data during mission anomaly resolutions
  - *Inability to share* models in a collaborative environment
  - Ineffective use of precious *testing* time and resources
  - Too many design *reviews* that review documents instead of the design
  - System designs emerge from the *pieces*, not from an architecture
  - Use of *unvalidated models* in simulations leading to incorrect results

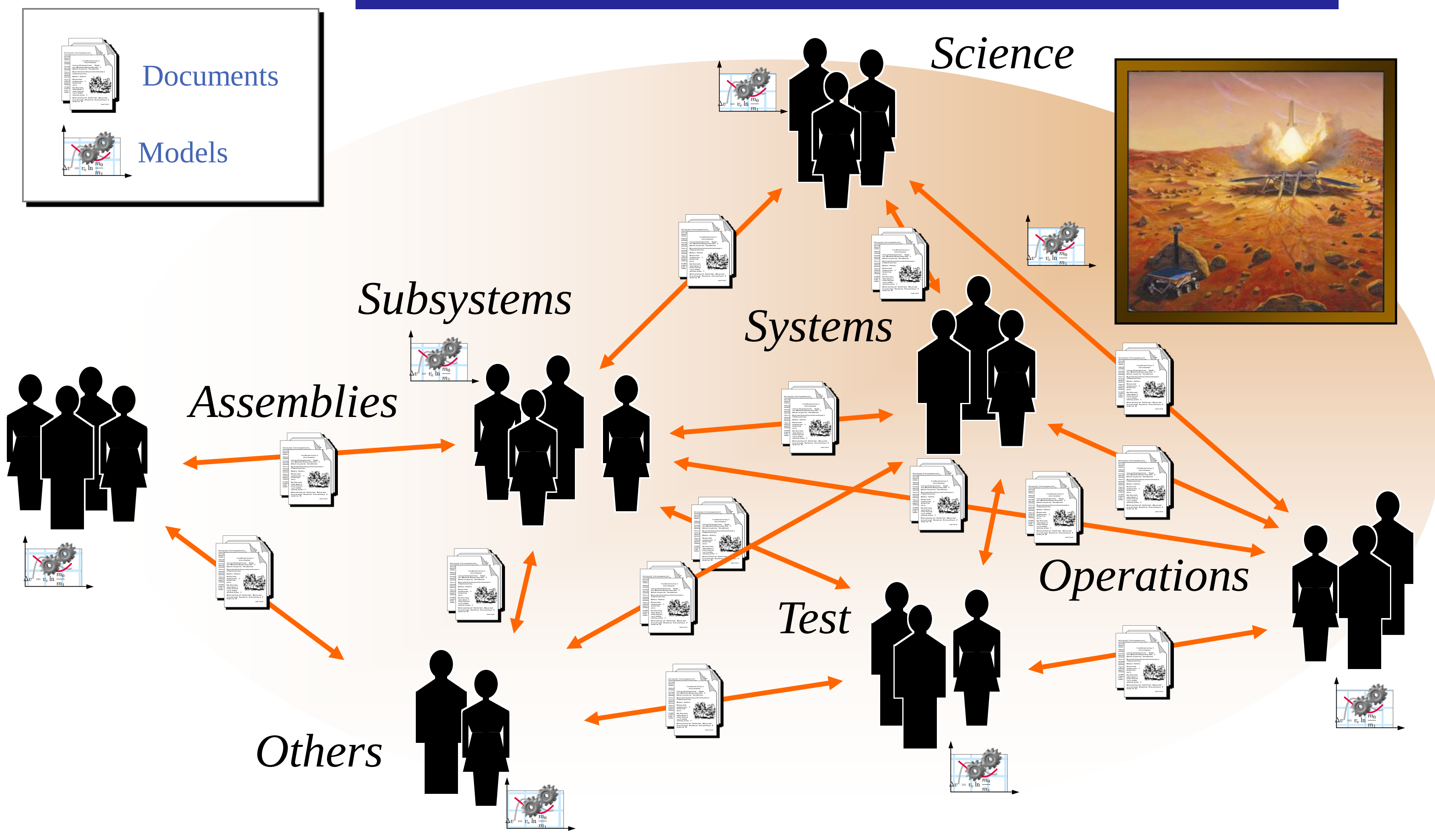
Some quick thoughts

- Moving to a more model-centric philosophy within the Agency will help resolve many of these issues
- It can (and must) enhance sound engineering practices and capabilities, but it can not replace them!
- It cannot solve all the issues
- It might not even solve the biggest issues
- But what we (engineering) do, we need to do better…
- … and we can do this

What does Model-Centric mean, anyway?

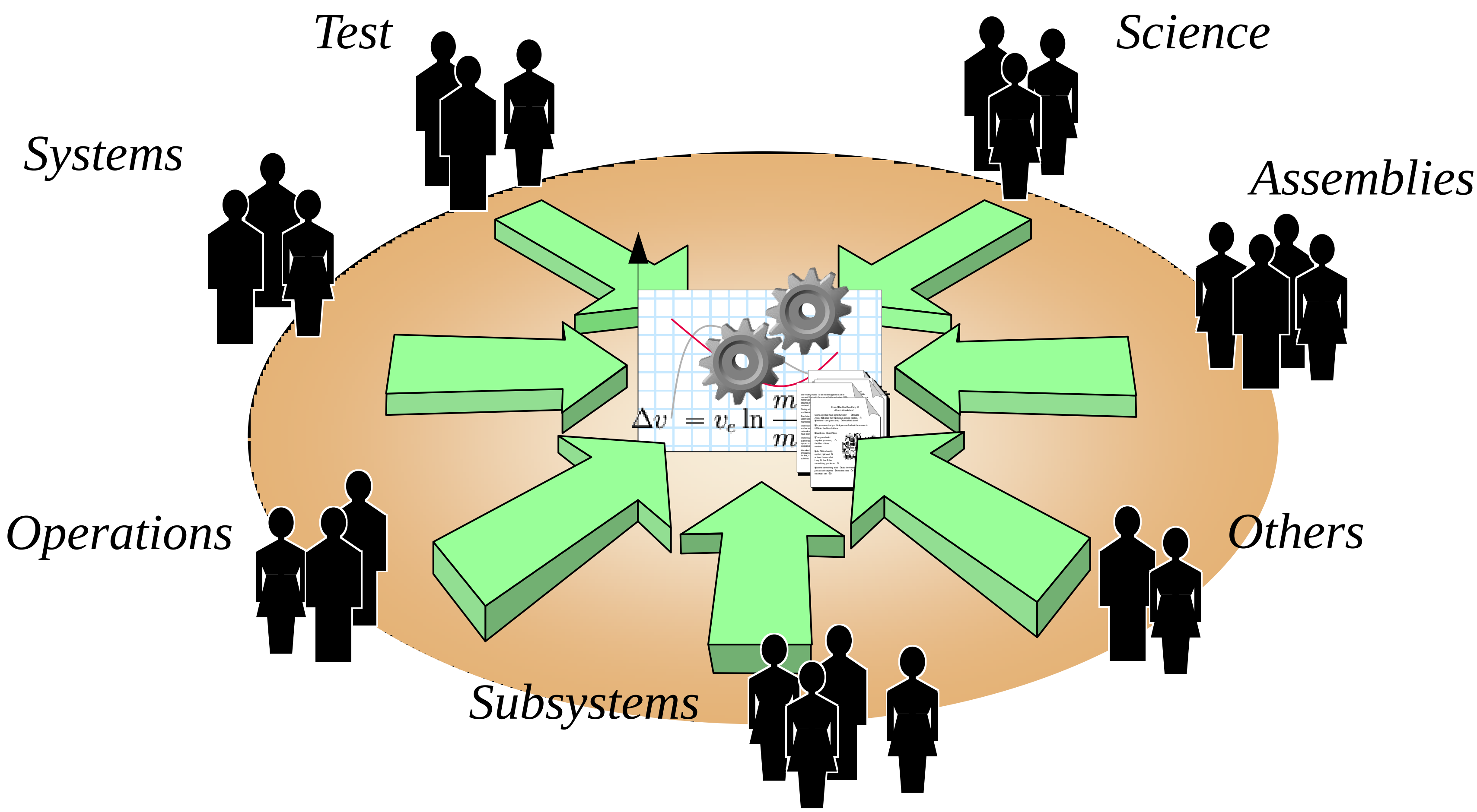
Document-Centric Engineering

Complex, Inefficient, Redundant, Error-prone



Model-Centric Engineering

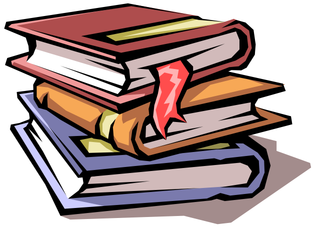
Compact, Efficient, Consistent, Manageable



What it's Not vs. What it Is

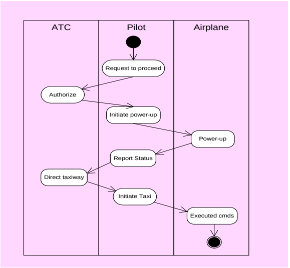
What it's Not	What it Is
It is not the selection or creation of a single multi-million dollar tool that is forced on everyone	The integration of many existing tools, databases and resources , evolving by necessity
A quick initiative that will instantly spring into being	Will take time and effort to slowly ingrain the methodologies and practices into the workforce
Extra work that would be required of all programs and projects	A more efficient and effective way of doing the kinds of things we already do
Is not "push-the-button and everything pops out"—does not take the place of sound engineering and management practices	Enhances the ability for projects and systems engineers to perform their real work

Past



- Concepts
- Requirements
- Engineering/Science Data
- Management
- System designs
- Analyses & Trade-offs
- Test plans
- Operations

Future

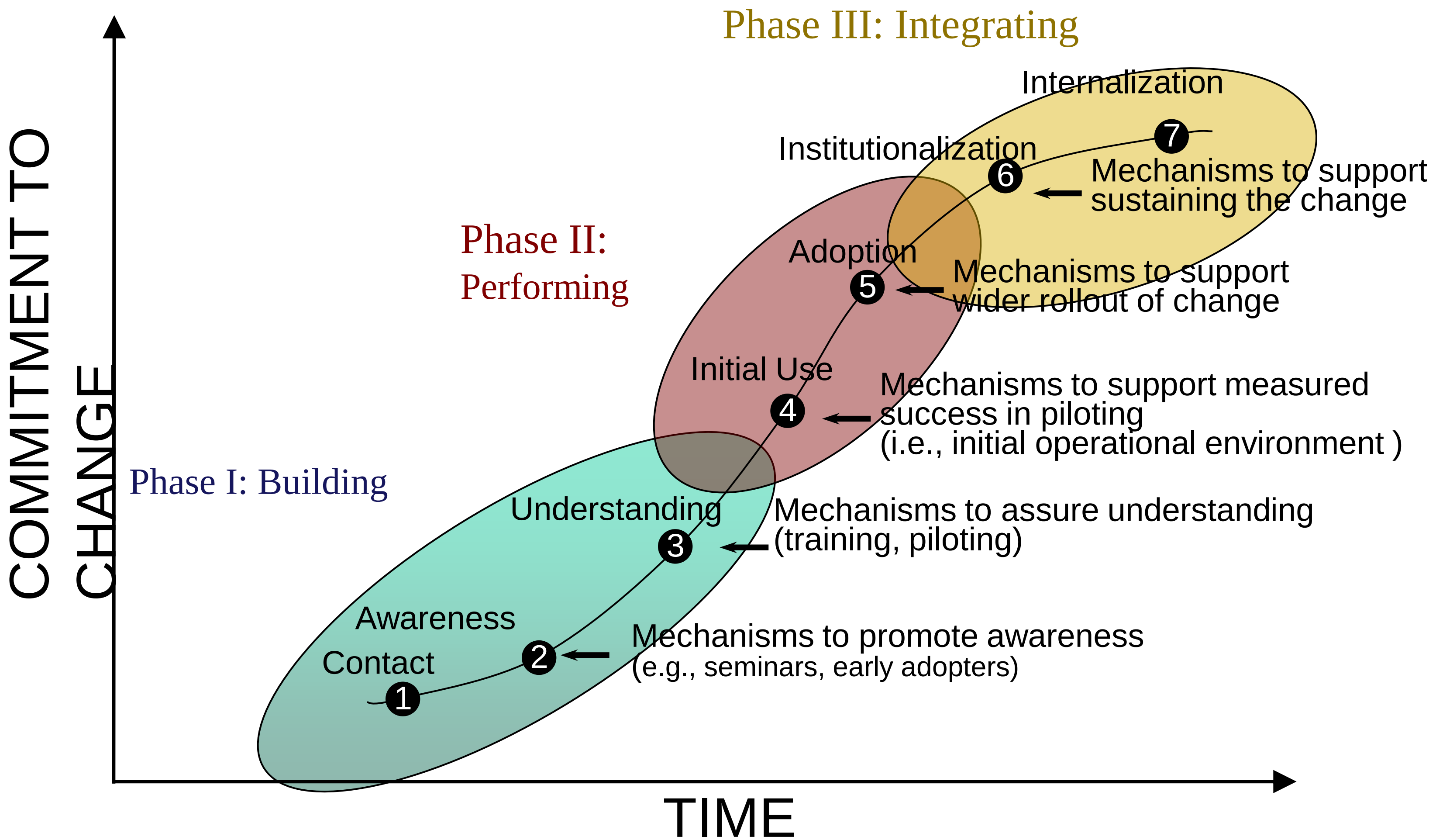


Moving from Document centric to Model (data) centric

Benefits

- Moving to a model-centric culture will provide many benefits
  - Enhanced affordability
  - Increased ability for collaboration
  - Identification of problems earlier
  - Quicker, more accurate diagnosis and resolution of mission anomalies
  - More effective use of testing resources
  - Better cost estimation and control
  - Better, more effective design reviews
  - Quicker understanding of cost, schedule and technical impacts of requirement or design changes
  - Enhanced ability to do systems engineering
  - Quicker and more accurate analysis/simulations
  - ***Consistent, repeatable engineering processes and products***
    - ***From project-to-project***
    - ***Over project lifecycle***

Cultural Change Roadmap

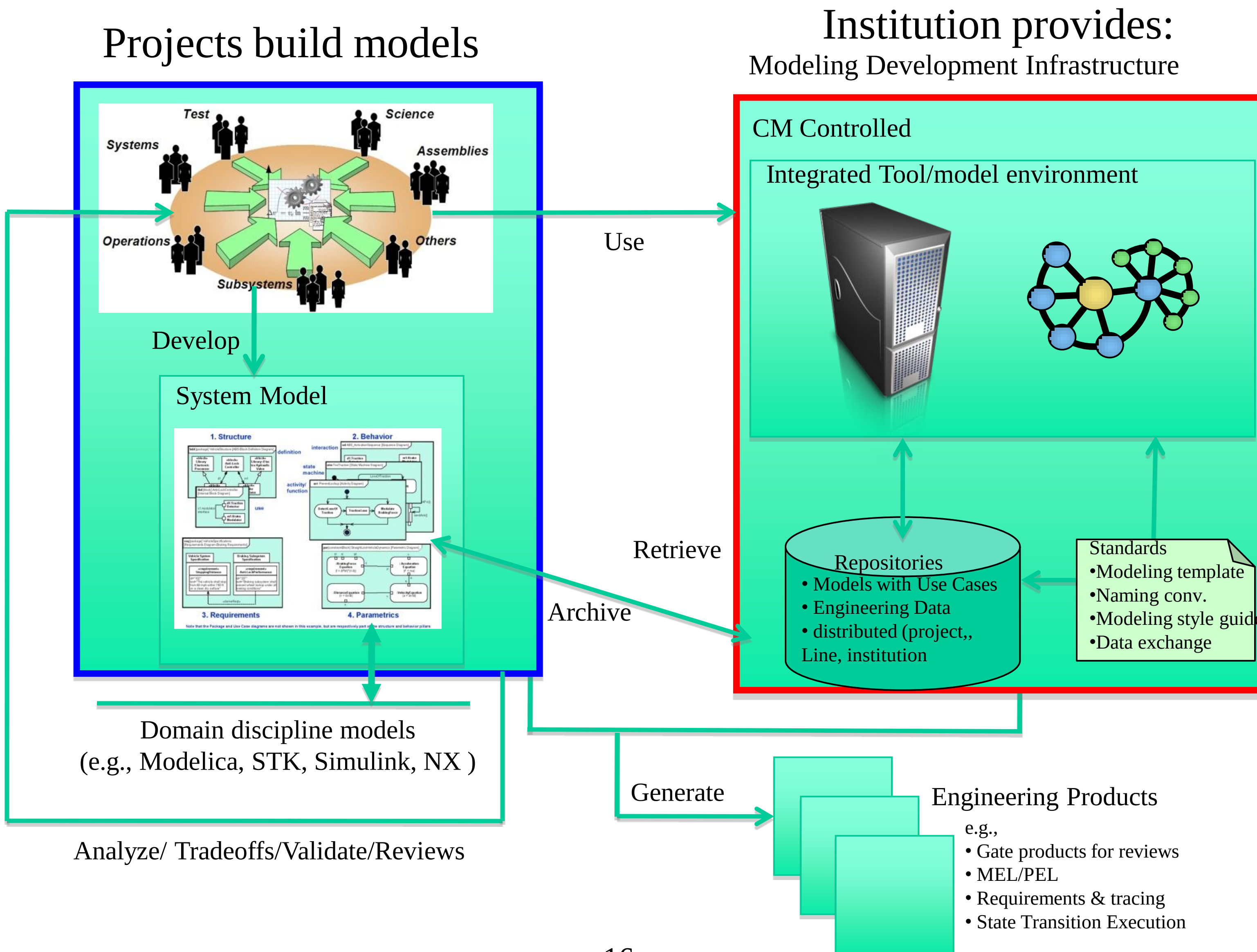


Adapted from "Out from Dependency: Thriving as an Insurgent in a Sometimes Hostile Environment", SuZ Garcia and Chuck Myers, SEPG Conference, 2001

Requirements for Successful Transition

- Non-technical
  - Resources
  - Leadership
  - Grass roots
  - Communication
  - Workforce skills
  - An *appropriately disruptive* approach
  - Buy-in at all levels (willingness to change)
- Technical (to-be state)
  - Architecture (Framework)
  - ConOps
  - Standards
    - Data
    - Tools
    - Methods
    - Processes
    - Lexicon (Ontologies)
    - Infrastructure

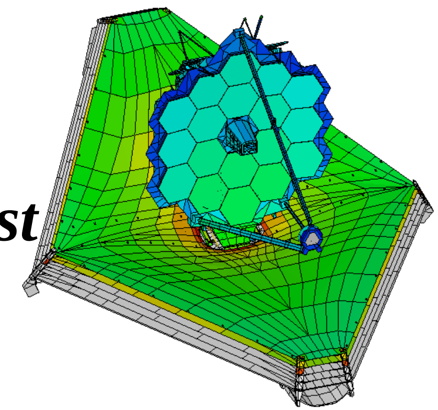
One Possible Model: JPL IMCE Concept



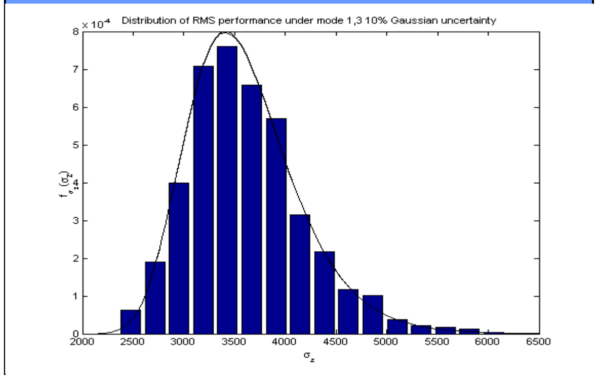
NIMA Communities of Practice

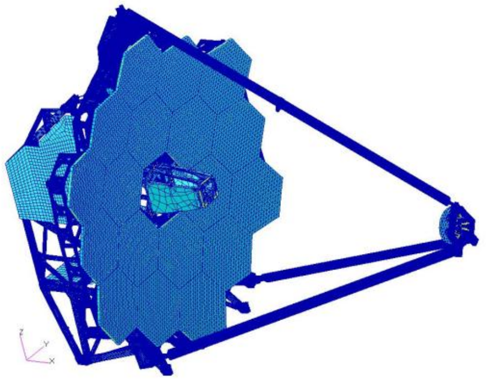
M&S

- Most mature of the 4 CoP's
- Strong collection of legacy M&S tools
  - Both a pro and a con…
- ***Needs & opportunities for improvements exist***
  - Standards and formal practices
    - NASA-STD-7009, NASA-HDBK-7009
  - Tool-to-tool integration & interoperability
  - ***Use of probabilistic technologies***
  - ***Use of super computing technologies***



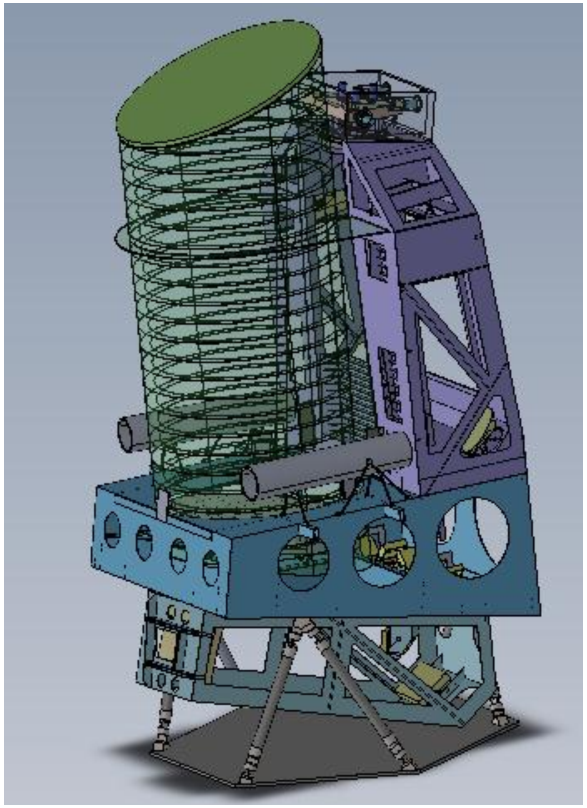
Output distribution

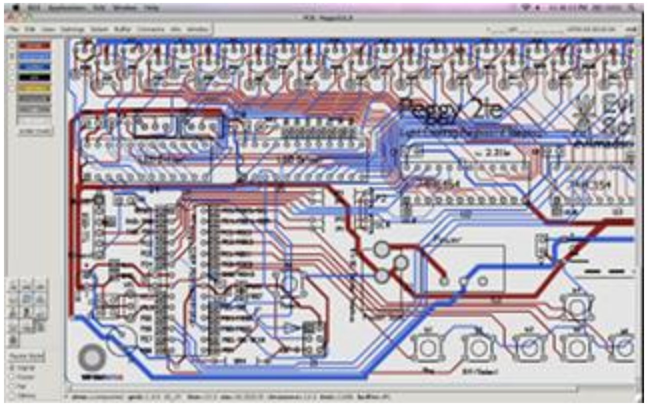




CAD

- Fairly mature and robust capabilities for both mechanical (MCAD) and electrical (ECAD)
- Interface/interoperability issues exist, somewhat similar to M&S domain
- First to integrate with PDLM

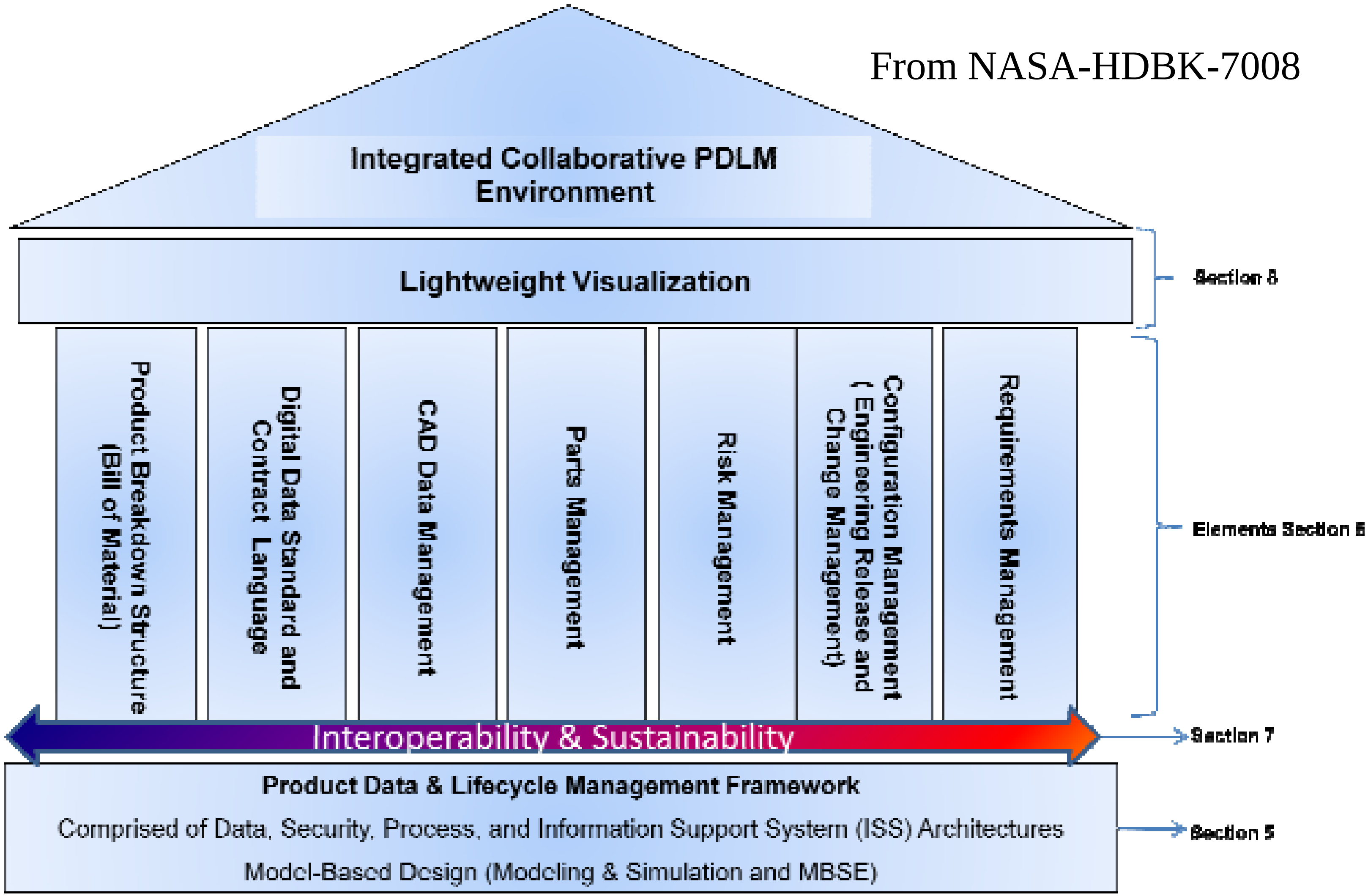




PDLM

- Is the process of managing the entire lifecycle of a product from its conception, through design and manufacture, to service and disposal.
- Integrates people, data, processes and business systems and provides a product information backbone for companies and their extended enterprise.
- ***Centralized repository (logical, if not physical) provides a configuration-controlled, authoritative source of data***
- Multiple COTS software solutions, e.g. Windchill, Teamcenter, Anovia
  - ***Generally provide workflow automation***
- NPR 7120.9, NASA-HDBK-7008
- ***Lessons Learned: ICE (CxP)***

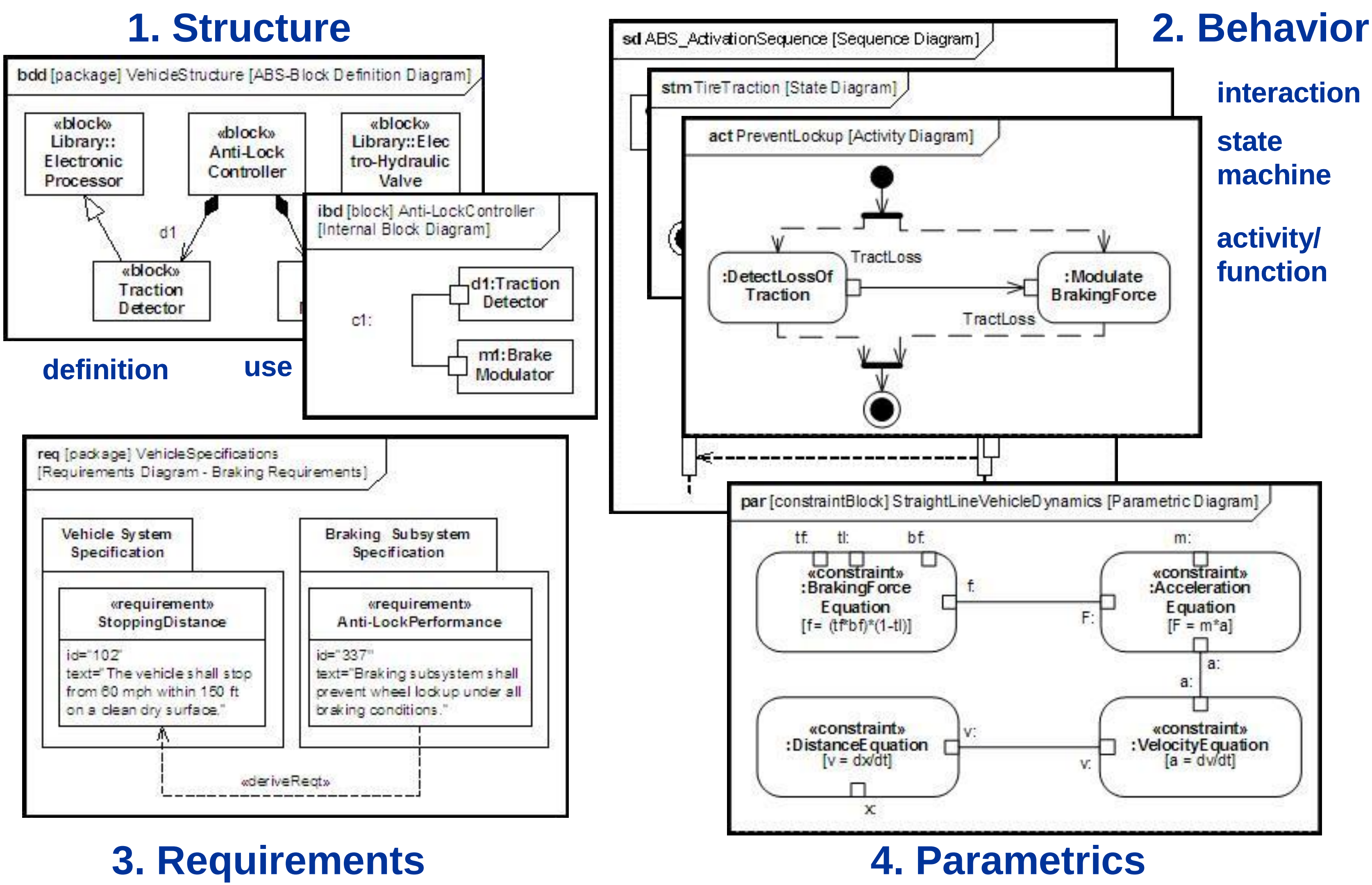
Notional PDLM Framework



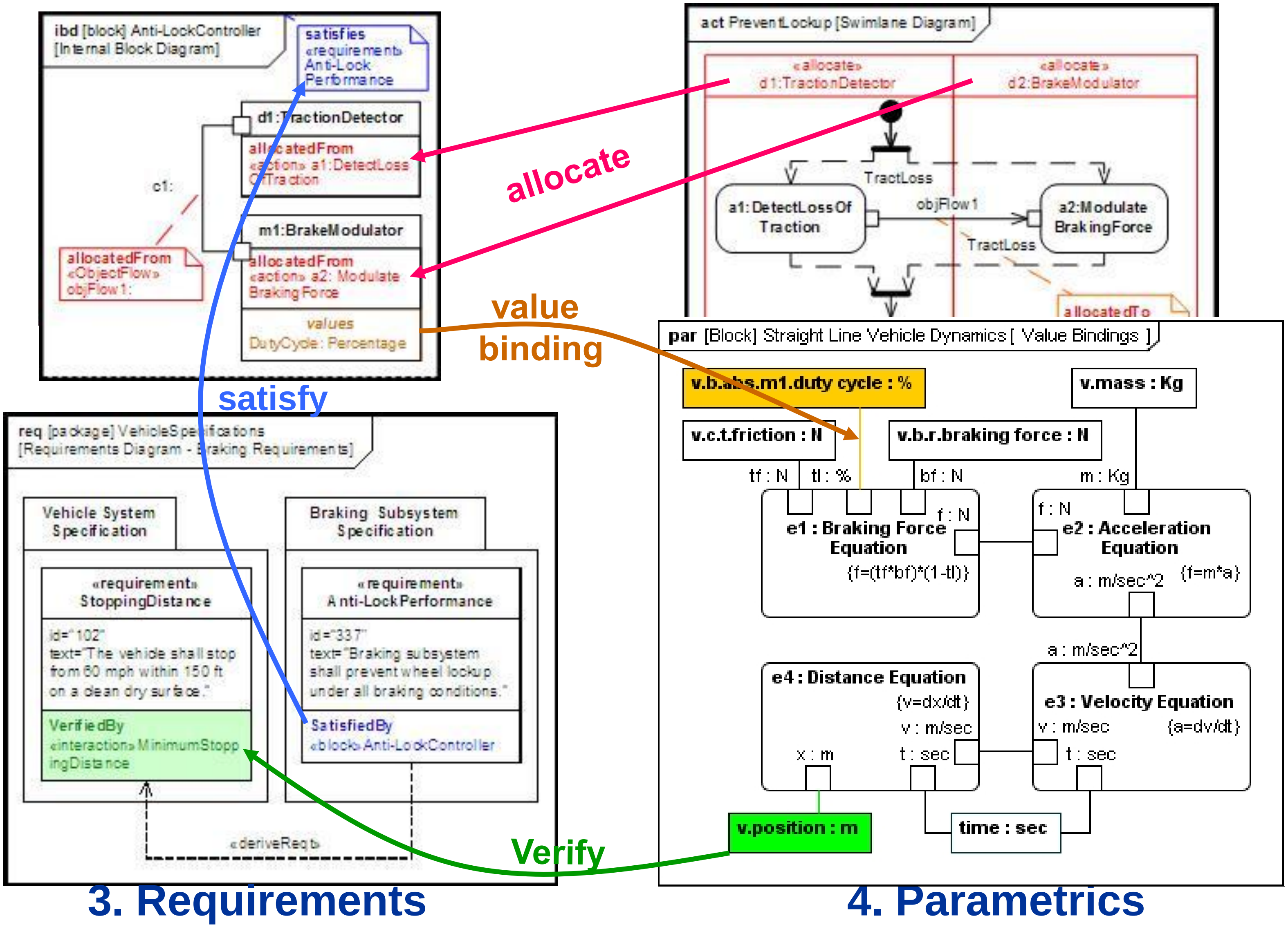
MBSE

- ***MBSE is a practice of applying modeling for implementing the processes and practices of systems engineering through the use of models and modeling***. [Ref: NASA MBSE WG]
  - The processes and practices referred to in this definition are those as defined in NPR 7123.1
    - Model: An abstract representation of a system, entity, phenomenon, or process
    - Modeling: Application of a standard, rigorous, structured methodology to create, verify and validate a model or set of models
  - MBSE is not intended to encompass discipline specific modeling activities, such as computer aided design models, structural models, thermal models, software models, or other models that are specific to a discipline.
  - However, a MBSE approach could link all of these together through the use of a centralized model and tools that can exchange information with one another.
- Models are typically developed using graphical programming, or diagramming, tools, e.g. Core, Cradle, Rhapsody, Magic Draw.
- Separate tools are often required to use (analyze) the models.

Example: SysML Diagrams

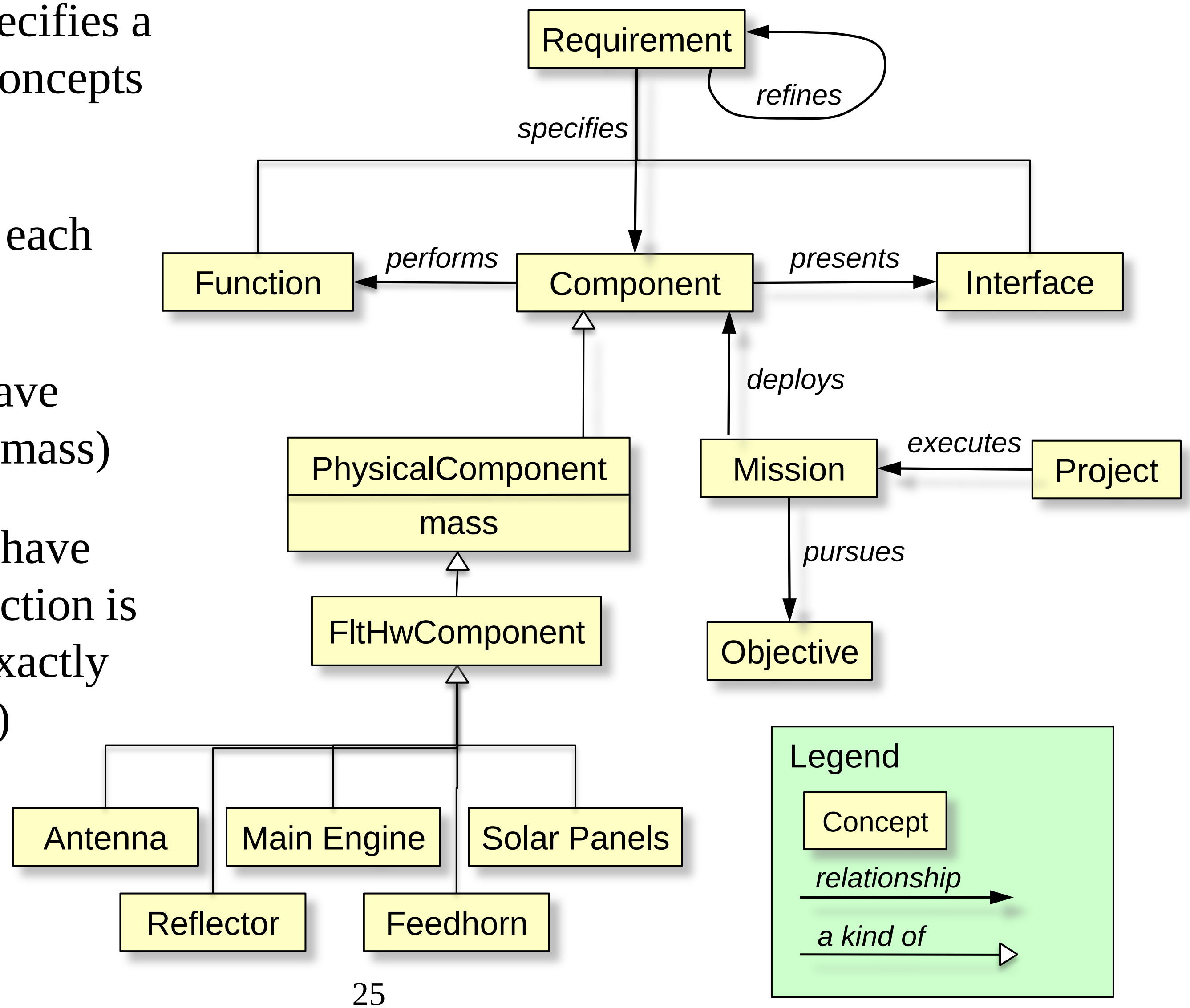


SysML Diagram Connectivity



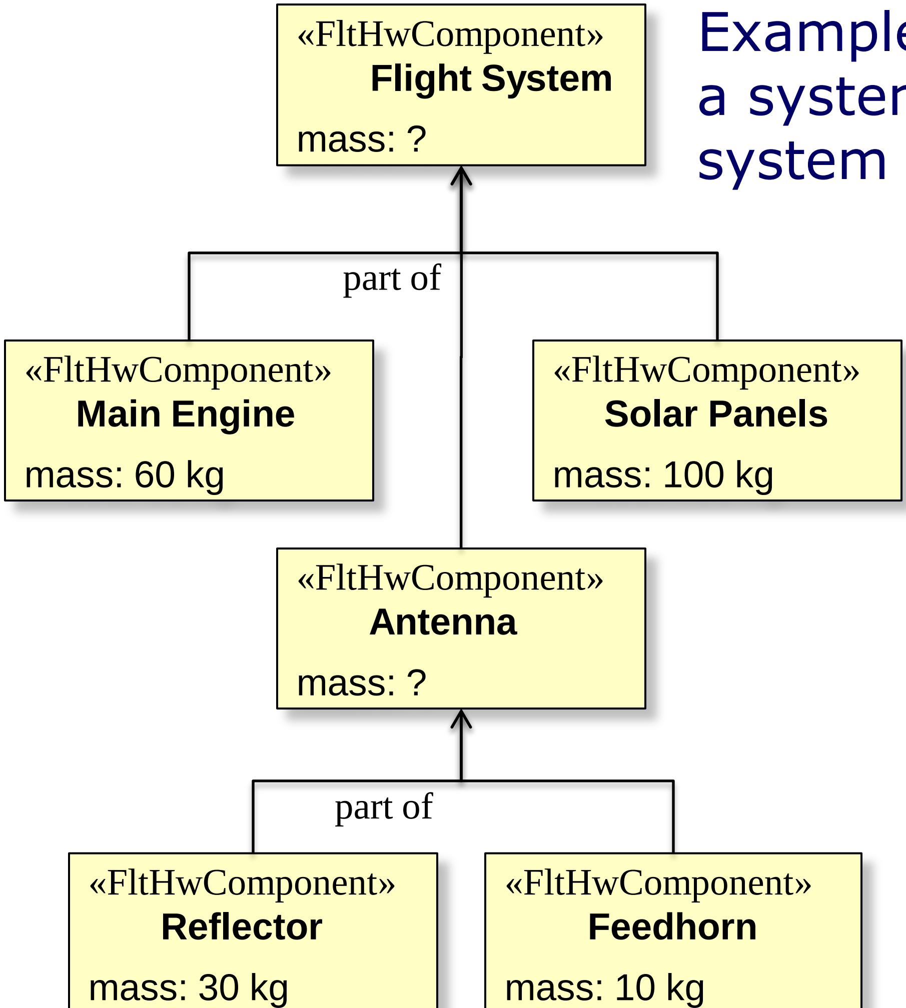
Basic of Ontologies

- An <u>ontology</u> specifies a vocabulary of concepts
- Concepts have <u>relationships</u> to each other
- Concepts can have <u>properties</u> (e.g. mass)
- Ontologies can have <u>rules</u> (e.g. a function is performed by exactly one component)



Ontologies Facilitate Analysis

Example: a simple algorithm can traverse a system model to calculate mass of flight system



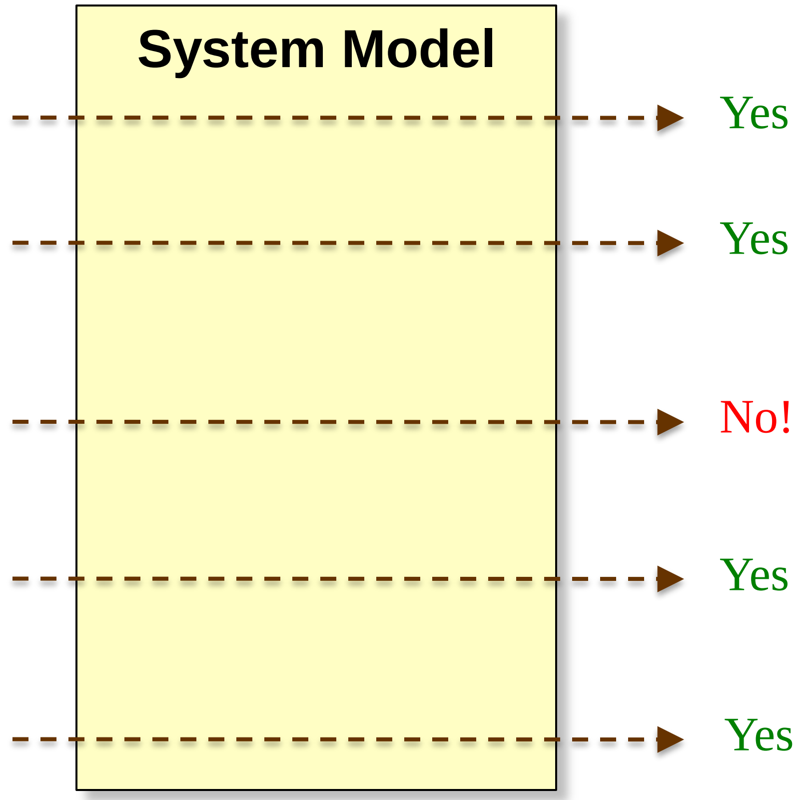
Algorithm

```
getMass (FlightHardwareComponent c) {
   my_mass = 0;
   if c has parts
   then
      for each part cc {
         my_mass += get_mass(cc);
      }
    else
      my_mass = c.mass;
   return my_mass;
}
```

Mass of flight system = 200 kg

More Analysis Examples

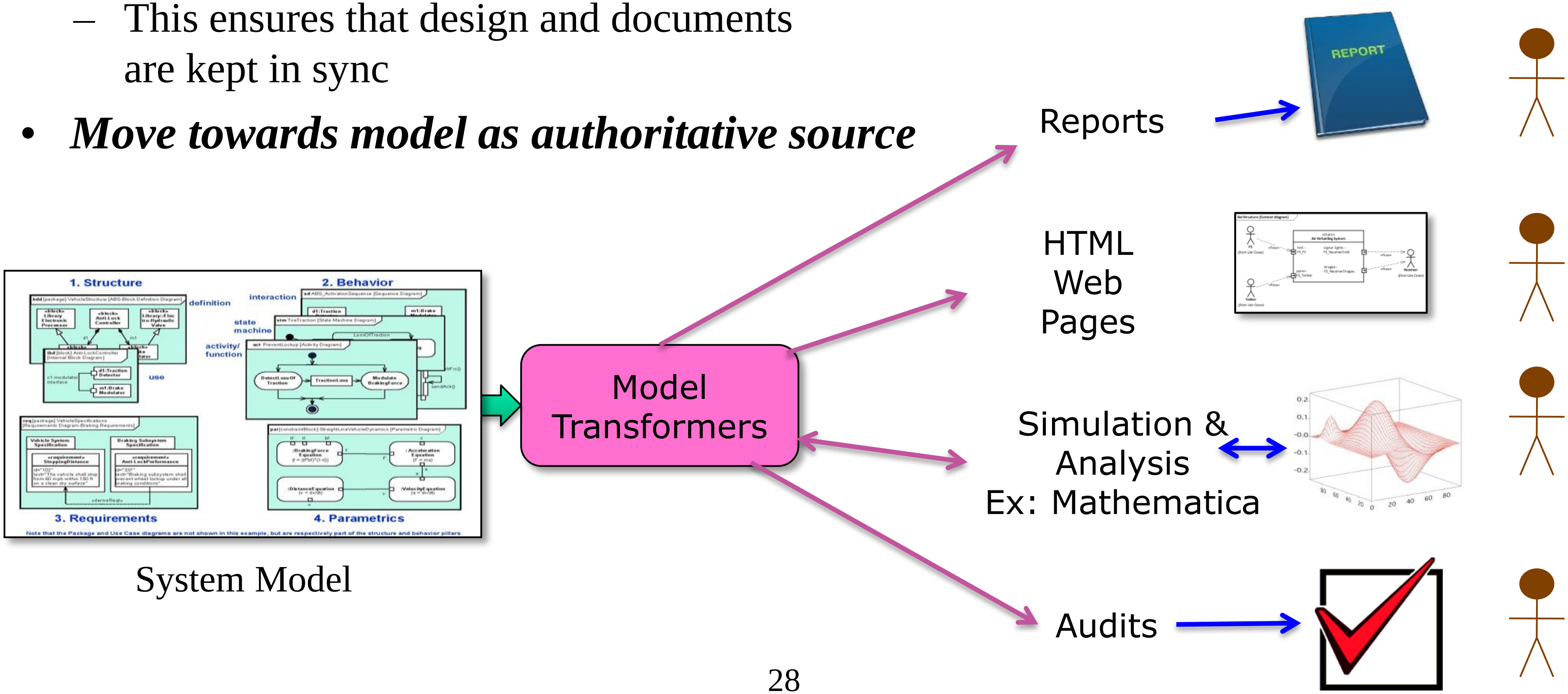
- A model can show if a design is complete with respect to its lifecycle phase
- Examples:
  - Are all requirements flowed down?
  - Does every component trace to a requirement?
  - Is every function allocated to a component?
  - Have both sides of every interface been specified?
  - Are all critical TBDs dispositioned?



Documents in a Model-Centric World

How does MBSE affect deliverables?

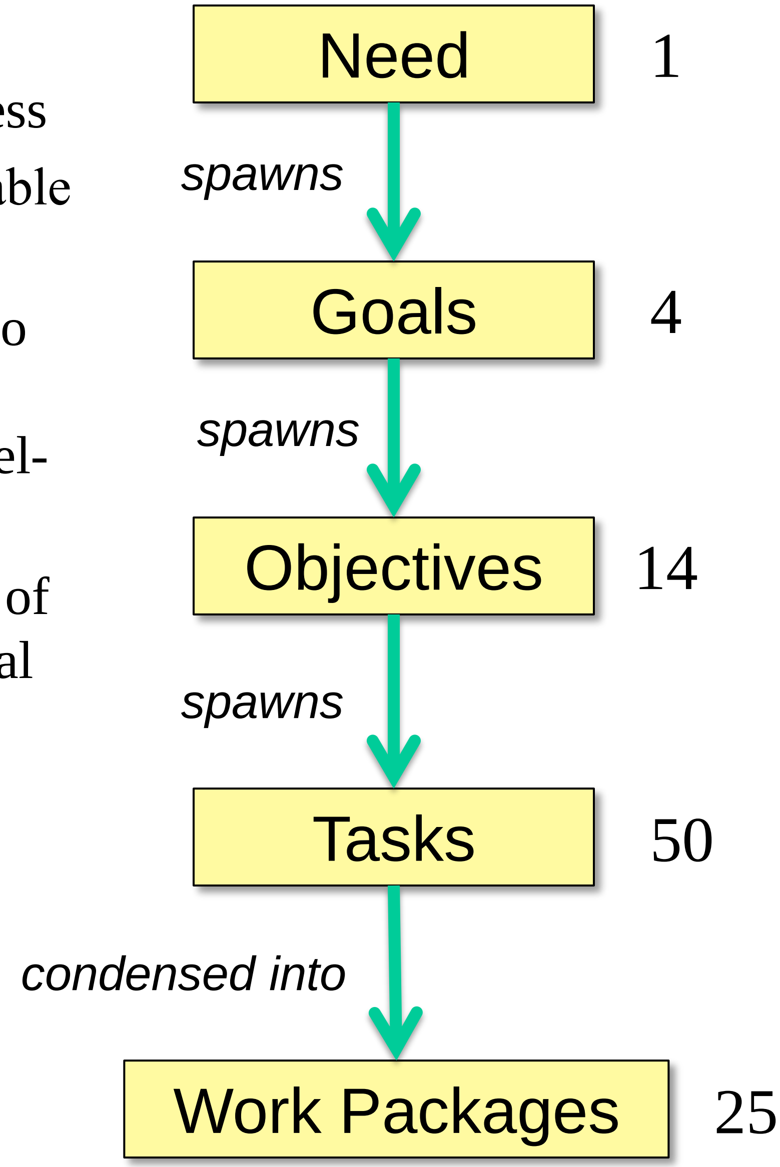
- Project still has to produce deliverables for each review
- ***Some documents may be generated automatically from system model***
  - This ensures that design and documents are kept in sync
- ***Move towards model as authoritative source***



What has NIMA done in the last year?

NIMA is Requirements Driven

- NGO's flowed down → 50 tasks
- Tasks analyzed for overlaps/completeness
- Tasks → 25 "Work Packages" all traceable to the NGO's and to CoP's
- Work Packages are activities that need to be performed to accomplish the work to start moving the agency towards a Model-centric architecture
- Teams were then formed around the set of work packages that are identified as focal points for the fiscal year
- Details available in backup charts



Current Teams

- **Team 1: Benchmarking** – this team is performing benchmarking trips and research
- **Team 2: Foundations** – this team is looking at model-centric fundamentals, i.e. architecture frameworks, data integrity, use and reuse of models
- **Team 3: Current Architecture** – this team is identifying the current existing data and IT architectures at each of the centers and its readiness to handle moving to a model-centric culture
- **Team 4: ConOps** – this team is describing a user's view of how a model-centric approach applies to NASA's projects
- **Team 5: Communications Plan** – this team is identifying who are our stakeholders, what are their expectations and how will we need to communicate with them to ensure the success of moving to a model-centric culture
- **Team 6: Pilots** – this team is identifying the work that is currently being performed at each of the centers and determining if additional pilots need to be initiated in FY12 in order to move a area forward in accomplishing the model-centric architecture
- **Team 7: Workforce Capabilities** – this team is looking at what capabilities/skills will be needed to accomplish a model-centric culture, what capabilities/skills we already have, determine capability/skill gaps and develop a training plan for closing that gap
- **Team 8: Versioning and CM** – this team is identifying how data products are configuration managed and how to coordinate when the versions of the model-centric applications are changed

NIMA is ConOps Driven

- Use Case Examples (next 5 charts):
  - Determining the effect/impact of a requirement change
  - Designing a system
  - Verifying a system
  - Performing a review
  - Working a mission anomaly
- Additional Use Cases being developed
  - Note: As of May 2012, NIMA decided on an “eat your own dog food” philosophy. Requirements, Use Cases, Activities, Block diagrams and other aspects of the model-centric environment are being developed (modeled) using MBSE tools and methods

Determining an Effect of a Requirement Change

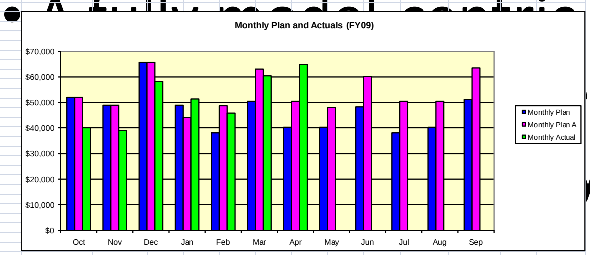
- Premise: Late in a development cycle a key requirement is changed.
- A fully model centric program will … ffect of that … viewpoints

This Plan A is an adjusted Plan to reflect the current requirements

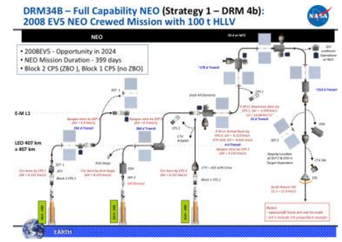
CHeCS All Subsystems	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
	Planned	Planned	Planned	Planned	Planned	Planned	Planned	Planned	Planned	Planned	Planned	Planned
Total Labor	[illegible]	$45,689	[illegible]	[illegible]	$35,567	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	$37,593	[illegible]
Plan	$48,447	$45,689	$61,240	$41,130	$45,351	$58,697	$46,964	$44,750	$56,167	$46,964	$46,964	$56,515
Total NonLabor	$0	$0	[illegible]	$0	$0	$0	[illegible]	$0	[illegible]	$0	[illegible]	[illegible]
Fee (at 100%)	[illegible]	[illegible]	[illegible]	[illegible]	$2,579	[illegible]	$2,725	[illegible]	[illegible]	[illegible]	$2,725	[illegible]
Total Cost Plus Fee	$51,959	$49,001	$65,680	$49,001	$38,146	$50,390	$40,318	$40,318	$48,219	$38,146	$40,318	$51,012
Cummulative	$51,959	$100,961	$166,641	$215,642	$253,788	$304,178	$344,497	$384,815	$433,034	$471,179	$511,498	$562,510

CHeCS All Subsystems	Oct		Nov		Dec		Jan		Feb		Mar	
	Planned	Actual	Planned	Actual	Planned	Actual	Planned	Actual	Planned	Actual	Planned	Actual
Total Labor	[illegible]	$37,276	[illegible]	$36,438	$61,240	$54,236	[illegible]	$47,949	[illegible]	$42,325	[illegible]	$56,048
Total NonLabor	$0	$0	$0	$0	$0	$0	[illegible]	$0	$0	$345	$0	$272
Fee (at 100%)	$3,512	$2,703	$3,312	$2,642	$4,440	$3,932	$2,982	$3,476	$3,288	$3,094	$4,256	$4,083
Total Cost Plus Fee	$51,959	$39,979	$49,001	$39,080	$65,680	$58,168	$44,112	$51,425	$48,639	$45,764	$62,953	$60,403
Cumm. Forecast	$51,959	$39,979	$88,980	$79,058	$144,738	$137,226	$181,338	$188,652	$237,291	$234,415	$297,368	$294,818

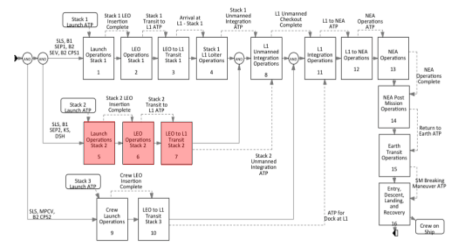
Cost Impacts



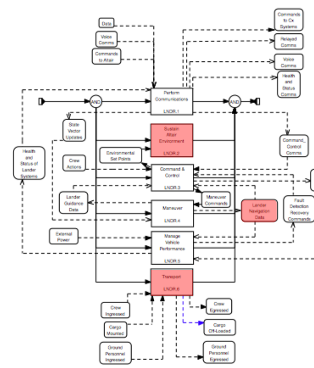
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Monthly Plan	$51,959	$49,001	$65,680	$49,001	$38,146	$50,390	$40,318	$40,318	$48,219	$38,146	$40,318	$51,012
Monthly Plan A	$51,959	$49,001	$65,680	$44,112	$48,639	$62,953	$50,369	$47,994	$60,239	$50,369	$50,369	$63,406
Monthly Actual	$39,979	$39,080	$58,168	$51,425	$45,764	$60,403	$64,781	$0	$0	$0	$0	$0



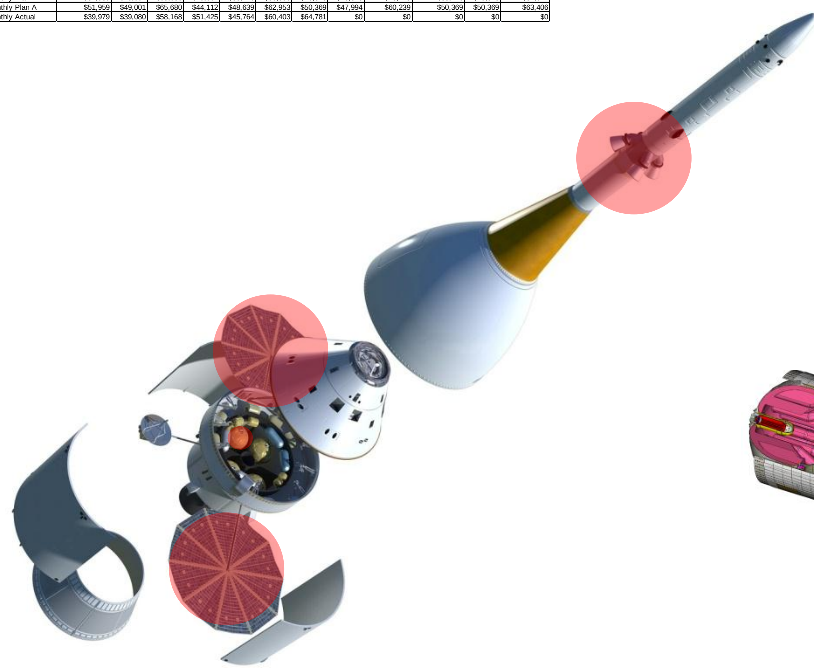
DRM Affected

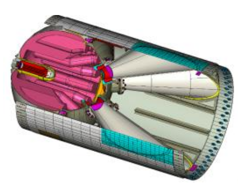


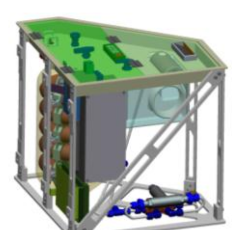
Mission Segment Affected

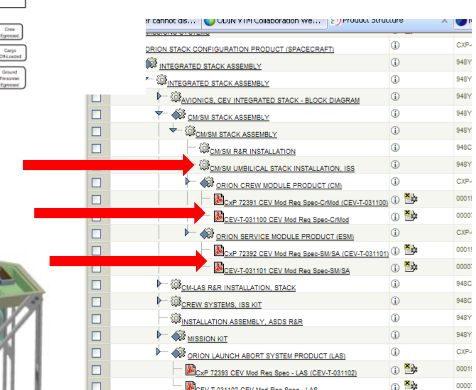


Functions Affected





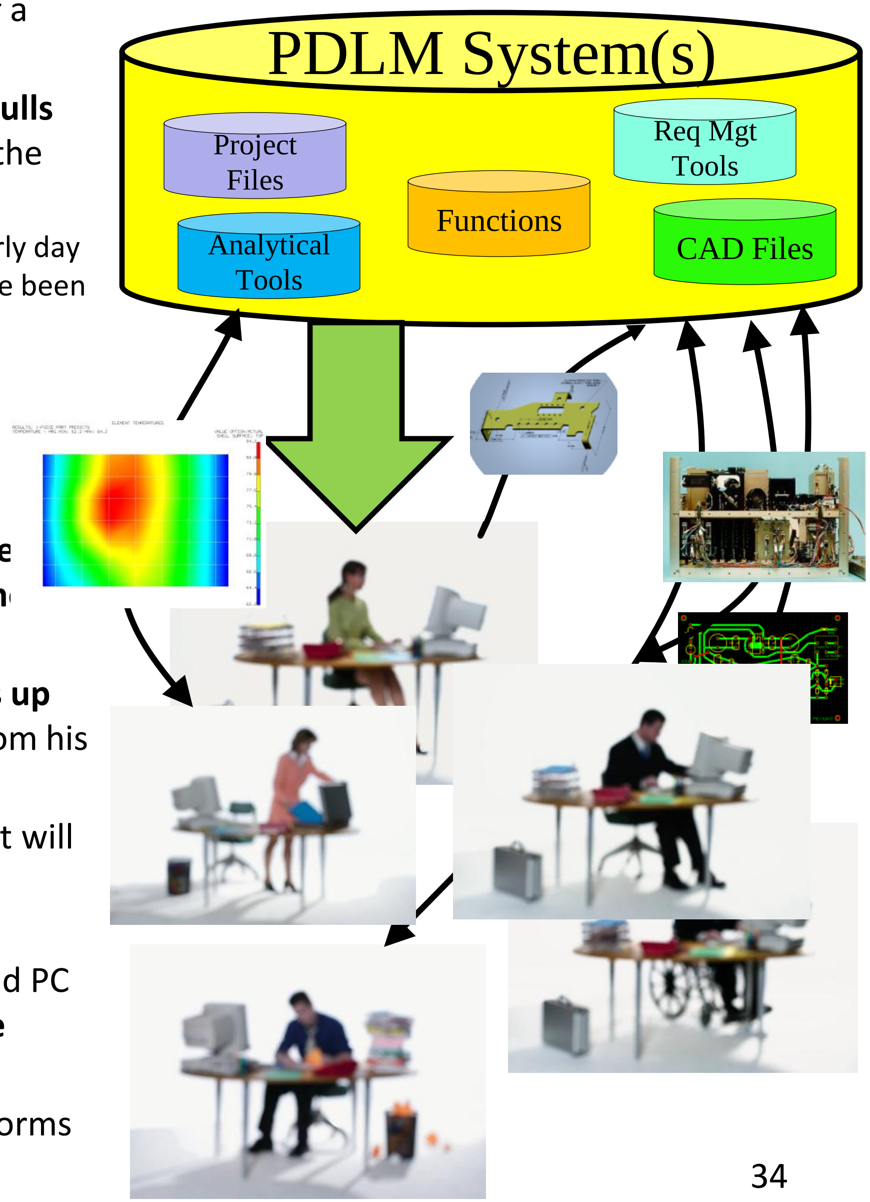




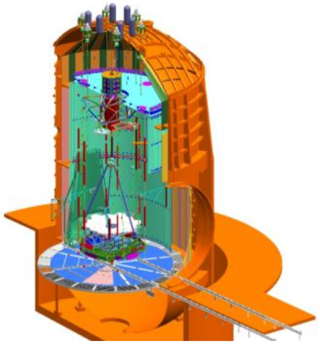
Parts Affected

Designing a System

- A project team is pulled together to develop the design of a portion of a spacecraft
- The bracket designer sits down at their workstation and **pulls up information** developed during the previous phases of the lifecycle:
  - a concept of operations that has been maturing from the early day one thoughts to the more detailed current concepts that have been agreed to by all stakeholders and the customer
  - A set of requirements allocated to his specific system
  - A set of functional and behavioral diagrams that have their associated allocated requirements
- From this information she begins developing the physical design at his CAD workstation and when finished **stores he portion of the design into the designated authoritative m database.**
- The avionics enclosure designer at a different center **pulls up the bracket model** and begins augmenting with details from his assignment
- The avionics electrical engineer designs the PC boards that will go into the enclosure and **stores the results in the authoritative model database**
- The Systems integrator **pulls up the bracket**, enclosure and PC boards to form an integrated model which is **stored in the authoritative model database**
- A thermal analyst **pulls up the integrated model** and performs a thermal analysis **storing the results into the database**.



Verifying a System



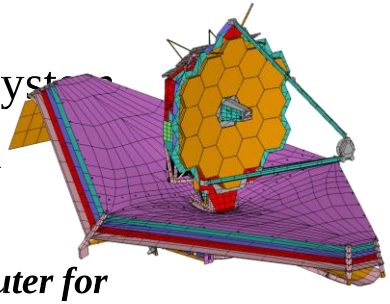
Test (at JSC):

- JWST TVAC test performed at JSC chamber A
- Test data collected and archived in PDLM system

Model Correlation & Update (at GSFC and NGAS):

- Thermal model for JSC A configuration retrieved from PDLM system
- Model parameters adjusted such that simulated and measured test responses agree within acceptable error bounds
  - ***Simulation effort requires large number of runs on high-performance computer for meaningful model validation***
- Updated thermal model saved to PDLM system

Verify on-orbit Performance (at GSFC and NGAS):



- Thermal model for on-orbit configuration retrieved from PDLM system
- Updated common model parameters transferred to on-orbit model
- On-orbit performance verified by simulation
  - ***Simulation effort requires large number of runs on high-performance computer for meaningful performance verification (uncertainty quantification and sensitivity analysis)***

Performing a Review

Review Preparation:

- Review success criteria specifies *viewpoints* (gate products) needed to address stakeholder concerns
- Reviewers examine the models using a browser or other model-viewing tools

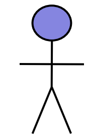
During the Review:

- Various types of models reviewed: system, hardware, software, CAD, analysis, verification
- Attention focused on *models* using model-viewing tools, not PowerPoint slides
- Presenters are "tour guides" through the models
- Reviewers know how to *read* the model views but do not have to use the modeling tools
- Reviewers assess design by asking probing questions
- Presenter navigates thru "live" model to answer questions

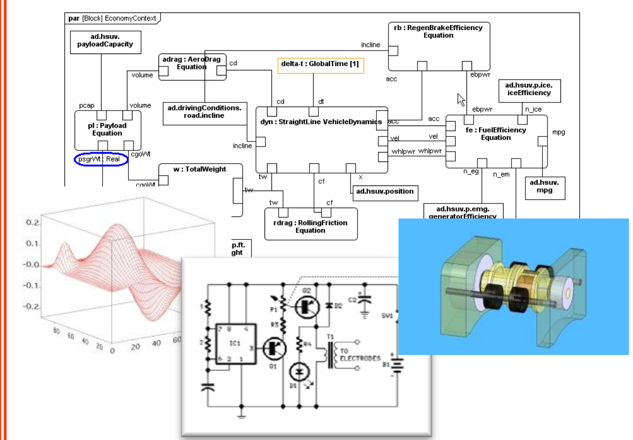
Review Follow-up:

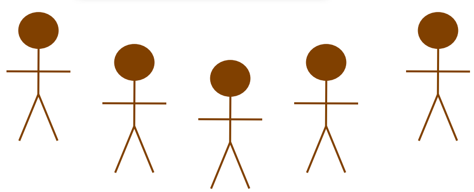
- RFAs linked to relevant model diagrams or packages
- Reviewers view RFA responses *in the models* using model-viewing tools

Presenter
"tour guide"



Models





Reviewers

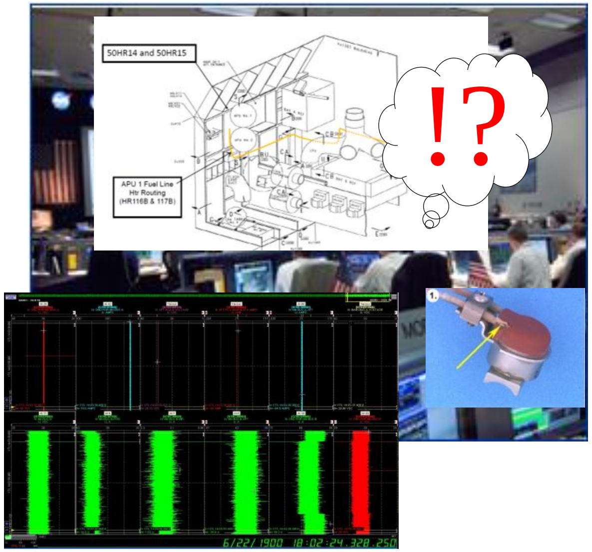
Working a Mission Anomaly

Its third shift and a small team is monitoring the progress of the MPCV as it makes it way towards the moon.

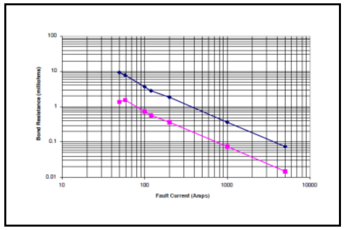
Suddenly the computer flags a problem with one of the on-board heaters. A call to the crew alerts them of the problem. They try to switch to the backup heater but to no avail. What is on the failed heater circuits? Can the parts withstand the expected cold? What could cause both heaters to fail? The ground and crew need information fast.

With a few keystrokes they pull up an integrated pictorial of the spacecraft and zoom in on the heaters. All design and certification data about each part is now at their fingertips. They can see what units are warmed by the heaters, and what temperature range they were certified for, find that they have about 30 minutes before they go out of their range.

They run a simulation and see that they can gain 4 hours if they roll the craft 90 degrees the affected circuits will be place in the sun and they will still have communication line-of-sight with the ground. As the roll maneuver is called up to the crew the engineering support team is checking in via their workstations and begin to work the problem



Freq. (MHz)	Measured Emission (dBµV/m)	Specification Limit (dBµV/m)	Exceedance (dB)	Data Plot Figure
234.220	31.600	31.369	0.231	A-1
250.450	35.300	31.950	3.350	A-2
264.830	35.700	32.433	3.267	A-3
281.360	33.500	32.958	0.542	A-4
283.180	33.900	33.014	0.886	A-5
289.570	34.200	33.207	0.993	A-6
299.440	35.700	33.498	2.202	A-6
313.640	35.200	33.900	1.300	A-4
323.780	36.500	34.175	2.325	A-1
329.400	35.700	34.324	1.376	A-7
331.090	40.700	34.369	6.331	A-8
338.570	37.400	34.562	2.838	A-8
346.210	38.300	34.756	3.544	A-8
353.310	36.200	34.932	1.268	A-7
378.560	39.400	35.530	3.870	A-5
382.810	37.000	35.627	1.373	A-3
391.460	38.100	35.820	2.280	A-9
392.460	37.700	35.843	1.857	A-4
395.850	39.100	35.917	3.183	A-1
400.290	39.000	36.014	2.986	A-2
400.800	36.300	36.025	0.276	A-7
409.330	37.700	36.207	1.493	A-3
413.930	36.400	36.300	0.100	A-2



Many Other Use Cases over Lifecycle

- Use of a model-centric enterprise system throughout the lifecycle of a product will greatly enhance quality and affordability
  - Work products will be built and matured seamlessly eliminating need to re-create them over the lifecycle
- Example products are:

Pre-Phase A	Phase A	Phase B	Phase C	Phase D	Phase E	Phase F
Concept Studies	Concept & Tech Dev.	Prelim. Design	Final Design & Fab	Assembly, test & Launch	Ops & Sustainment	Closeout
Conceptual Models Cost Estimation	Requirements Functional Flows	CAD designs Analysis Models Prototype test data Refined Costs	Refined CAD Refined Analysis Engineering Data Manufacturing	Integration Simulations Verification Certification	Operations Anomalies Simulations Science Data	Decommissioning Simulations Data Archiving Final Costs

Current Status

Benchmarking

- External Benchmarking
  - ATK
  - Ford
  - Whirlpool
  - Joint Strike Fighter
  - Lockheed Martin (Denver)
  - Pratt-Whitney Rocketdyne
- Internal benchmarking
  - JPL
  - JSC
- Formal report due in FY12, completing WP1

Initial Impressions of Benchmarking Team

- Whether developing spacecraft, aircraft, automobiles or washing machines we are all struggling with similar engineering and affordability issues
- All companies interviewed see their movement to a model-centric culture as vital to the long-term health of their businesses (see quotes on next chart)
- Most have mentioned that it is vital to have support from the top and buy-in at all levels throughout the company
- Like us, the companies have pockets of personnel using these techniques and are now looking at integrating them together
  - Most companies have established a standard set of applications to be uniformly used by all divisions/organizations within their company and their prime vendors
  - So when they use PDLM techniques, they will use the same tool. Likewise for CAD and M&S

Quotable Quotes

- “With today’s economy we couldn’t afford NOT to do this”
- “We have been seeing a lot of positive benefits. [These techniques] may add a bit more cost in design, but save a lot downstream.”
- The working force needs to see the value of the methods before they will adopt them.”
- “We find the use of these tools actually enables creativity and does it in time to have an impact”
- “Model based engineering has many keys to breaking the spiral of cost and schedule over-runs. But MBE must be used early and often as possible to see the real benefit”
- “Leadership must make a solid commitment”
- “We had been watching the grass roots efforts for some time. When corporate bought in it really took off”.
- “To be successful, this needs strong support from top management, needs time to mature and needs strong common processes”
- “Model based design is imperative, not discretionary”
- “A system architectural model is the loom that weaves many threads”

FY12-13 Pilots

- "Do" Pilots: The pilot involves developing a tool or actively implementing an aspect of NIMA
  - Model Integration and Standards Test-bed (MIST) (GSFC)
  - ❖ Program Model Data Exchange Tool (HQ)
  - AES Water Recovery System (JSC)
  - ❖ Model-based Project Control (ARC)
  - ❖ Small Mission Pilots (ARC)
  - ❖ NIMA Project Model
- "Watch" Pilots: This type of pilot involves an evaluation of a project of interest against relevant aspects of NIMA
  - HEOMD (ARC)
    - IFATT
    - VMDB/PRACA
  - Europa Habitability Mission (JPL)
  - Solar Moisture Active Passive (JPL)
  - Mission Operations System (MOS) 2.0 (JPL)
  - Integrated Model-Centric Engineering (JPL)
  - AES SharePoint Data Management (JSC)
  - Digital Collaborative Environment (DCE) (KSC)

❖ *Proposed FY13 content, pending resource availability*

Future Plans

Current Tasks That Will Continue in FY13

- WP8 (Reuse of Models)
- WP9 (Data Integrity)
- WP16,WP17 (Model Exchange & Framework)
- WP12,WP14 (Current/Future IT Architectures)
- WP13 (ConOps)
- WP15 (Communications Plan & Marketing)
- WP19 (Pilots)
- WP20 (Workforce Transition)
- WP18,WP23 (Versioning & CM)

New Tasks to pick up in FY13/FY14

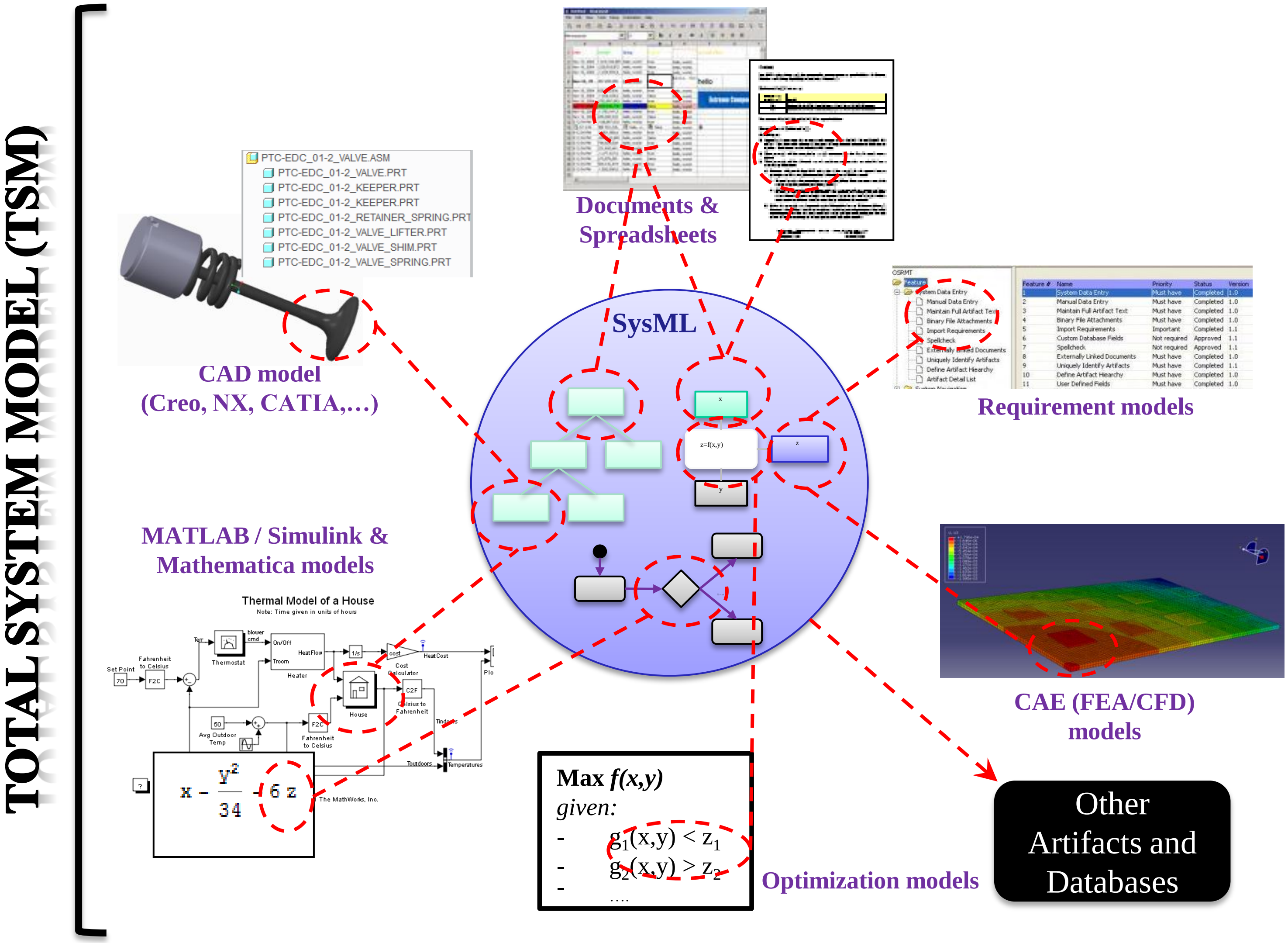
- WP4 (Design-to-Manufacturing)
- WP5 (Design and Interface Issues)
- WP7 (Authoritative Sources)
- WP21 (Standards)
- WP22 (Reviews)
- WP24 (Parts Libraries)
- WP25 (Instant Access)
- WP2 (Metrics)
- WP3 (Cost/Schedule Estimation)
- WP6 (Workflows)
- WP10 (Effective Use of Test Time)
- WP11 (Info about Parts)

Other Initiatives

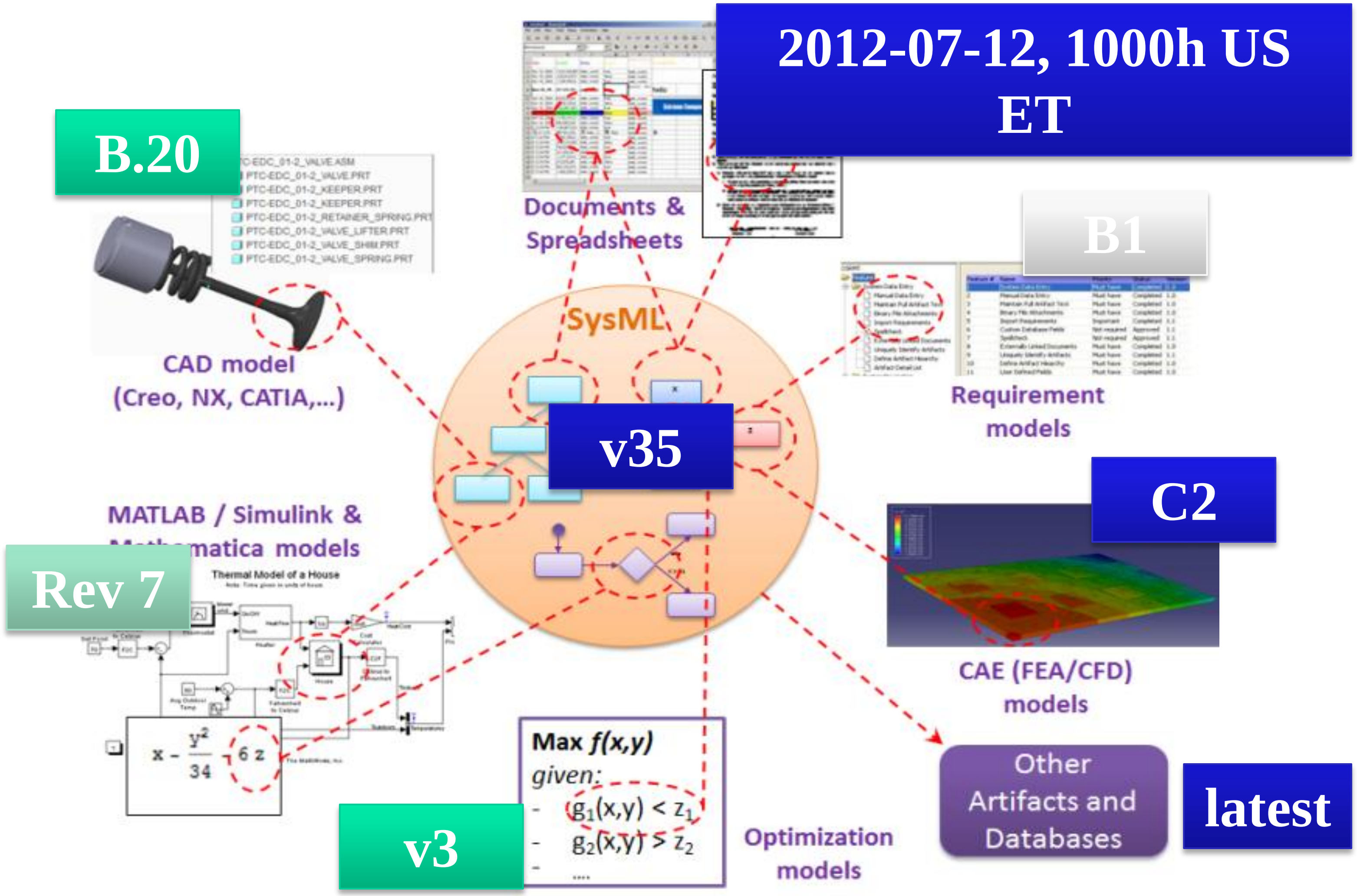
Beyond NIMA

- Many examples of Model-centric Engineering in use at other NASA centers (see backup charts)
  - Highlights:
    - Significant efforts in all 4 CoP's for CxP (now "Exploration Systems")
    - Significant investment in MBSE and advanced M&S at JPL
    - Significant investment in advanced M&S at ARC and LaRC
- GSFC: IRAD-funded Model-centric initiative started about one year before NIMA
  - Folded into NIMA, except for SysML pilot focused on IDC
  - May re-emerge as separate activity, involving 300/400/500/600/700
    - NIMA funding uncertainties
    - Move at our own pace
    - Concentrate on GSFC-specific issues
    - Still leverage NIMA to the extent possible
- SBIR: Subtopic S5.04 (Integrated Mission Modeling)
  - PY11 awarded Phase I to InterCAX for development of SLIM (Systems Lifecycle Management) linking SysML to PDLM

SLIM – Total System Model



SLIM – Model Management



Summary

Conclusion

- The NIMA effort is leveraging existing assets and work already being performed in the PDLM, MBSE, CAD and M&S communities
- NASA can make more effective use of its limited resources by setting a common vision, more effectively communicating between pockets of work being performed at the centers, integrating these activities and identifying new activities that would be beneficial to the agency model-centric goals
- There are many opportunities for collaboration between NASA, other government agencies, industry, professional societies and academia
- **YOU CAN HELP!**

Backup

Work Package Development

Needs Statement

To reduce cost, improve schedule, product quality and workforce performance through timely and well informed decision making, the Agency needs to move from document-centric to a model-centric architecture across the agency

Goals

- **Goal 1:** Increase *affordability* through use of a model-centric architecture
- **Goal 2:** Achieve *interoperability* within and among programs/projects, centers and external partners through use of a model-centric architecture
- **Goal 3:** Inform/train invigorate *workforce* on model-centric architecture
- **Goal 4:** Improve product *quality* and success through use of a model-centric architecture

Objectives

- **Goal 1:** Increase *affordability* through use of a model-centric architecture
  - Objective 1: Reduce life cycle *costs*
    - ✓ Do a cost/benefit analysis for model-centric architectures across the enterprise
      - Determine current enterprise architectures, where the future state is to be and determine gaps
    - Metrics/audits
    - Better cost/schedule estimating
    - Manufacturability
    - Identify design issues earlier
      - Better interface description and analysis
    - More efficient workflow/workforce
  - Objective 2: Facilitate good SE practices
    - Elegant design
    - Data integrity, content and flow
    - Authoritative source
    - Reduce technical risk
    - Reduce manual effort in the exchange of information among models and reuse of models
    - Good req
  - Objective 3: Reduce *Schedule* and schedule risk
    - Reduce rework through improved communication
    - Eliminate unnecessary data/format conversions
    - Less iteration of design through ability to have a larger trade space and selection of only the most feasible options (selection of optimized designs)
    - Focusing of test/analysis/demonstration/inspection cases
    - Quicker responses/analysis through accessibility to information and archived knowledge

✓ FY11 Tasks

Objectives (Cont'd)

- **Goal 2:** Achieve *interoperability* within and among programs/projects, centers and external partners through use of a model-centric architecture
  - Objective 1: Identify the interfaces for model and data information exchange
    - ✓ Determine current enterprise architectures, where the future state is to be and determine gaps
    - ✓ Identify stakeholders, platforms and gaps
    - ✓ Identify security needs
    - Identify platform maintenance requirements (outages)
    - ✓ Identify set of tools that are used
    - ✓ Define a concept of operations
  - Objective 2: Improve ability to share information
    - ✓ Address IT infrastructure issues – firewalls, authentification, tool centers, support services, help desk
    - Define requirements for CIO operations
    - Automated distributions and standardized reports
    - Export control and compartmentalization of data
    - Develop model transformations
    - Understand the data objects and attributes
    - ✓ Enhanced communication among stakeholders and users – common vision/goals
  - Objective 3: Adopt a architecture framework
    - Standardize and facilitate data exchange
    - ✓ Define ontologies
    - ✓ Governance
    - Versioning
  - Objective 4: Perform pilots and case studies of integrated MBSE, PDLM, M&S and/or CAD efforts
    - ✓ Identify pilots already being done
    - Establish opportunities for collaboration/guidance
    - ✓ Identify and execute need for new pilots

✓ FY11 Tasks

Objectives (Cont'd)

- **Goal 3:** Inform/train/invigorate *workforce* on model-centric architecture
  - ✓ Objective 1: Identify workforce resources and gaps of qualified personnel
  - Objective 2: Training
    - ✓ Awareness training/outreach on what model-centric is
      - Introductory module on model-centric MBSE, modeling, etc
      - SE overview
      - All personnel
    - In-depth training in key aspects of model-centric architectures
      - Developers
      - Users
      - SMA personnel
      - Etc.
    - ✓ Add modules into APPEL courses to show model-centric methodologies (action to steve to add module for PM/SE course)
  - Objective 3: Communication
    - ✓ Establish CoP websites (get with NEN to see if we can use them)
    - ✓ Roadshow to all centers/stakeholders
    - Yammer
    - E-journals/newsletters
    - Involve mid-level managers in how to evolve their operations and their employees
  - Objective 4: Benchmarking
    - ✓ Identify programs/projects that have used this successfully and use them as examples
    - ✓ Benchmark external organizations and bring back lessons learned

✓ FY11 Tasks

Objectives (Cont'd)

- **Goal 4:** Improve product *quality* and success through use of a model-centric architecture
  - Objective 1: Establish architectural foundations
    - ✓ Ontology and standards
    - Establishing a framework
  - Objective 2: Establish best practices/methodology
    - Greater access to product data for design reviews
    - Develop/Enhance CM
      - Traceability history of changes and rationale
      - Version and change control to ensure using the correct versions
    - Early identification of gaps and issues for integration
    - Enhanced ability to perform verifications
    - Less errors in translating to manufacturing of product from designs
    - Reuse of existing successful designs
      - Parts libraries
      - Object oriented libraries
    - Incrementally maturing models thought lifecycle
  - Objective 3: Enable greater insight/visibility into the product
    - Better informed decisions
    - ✓ Knowledge sharing and lessons learned within and across projects
    - Better support for Metrics/data on products
    - Ability to demonstrate success
    - Instant access to relative data to eliminate uncertainties

✓ FY11 Tasks

Tasks for each Goal/Objective

Goals	Objectives	Tasks/Initiatives	FY11 Task	FY12 Task
Goal 1: Increase affordability through use of a model-centric architecture	Objective 1: Reduce life cycle costs	1. Conduct a cost/benefit analysis for model-centric architectures across the NASA enterprise	X	X
		2. Determine what type of metrics/audits are needed to capture, monitor, control and understand life cycle costs		X
		3. Develop methodologies to enable better cost and schedule estimating		X
		4. Determine methodologies to reduce the cost of translating conceptual designs into the manufacturing of products (Design-to-Manufacturing)		X
		5. Determine what is needed to enable design and interface issues to be identified/analyzed earlier		X
		6. Develop techniques that will allow a more efficient workflow and use of the enterprise workforce		X
	Objective 2: Facilitate good SE practices	1. Determine methodologies that will enable/re-enforce good SE practices per NPR 7123.1		X
		2. Determine techniques for authoritative source idendification and use by the enterprise.		X
		3. Determine methodologies for the reuse of models and information exchange between models		X
		4. Determine methodologies to ensure data integrity, content and flow between internal and external NASA enterprise elements.		X
	Objective 3: Reduce Schedule and schedule risk	1. Determine methodologies that will minimize design iterations and rework and thus reduce schedules and/or allow a larger trade space.		X
		2. Determine methodologies that will allow more efficient/effective use of test time.		X
		3. Determine techniques that will allow effective accessibility to information about each part within a system		X

Tasks for each Goal/Objective (Cont'd)

Goals	Objectives	Tasks/Initiatives	FY11 Task	FY12 Task
Goal 2: Achieve interoperability within and among programs/projects, centers and external partners through use of a model-centric architecture	Objective 1: Identify the interfaces for model and data information exchange	1. Determine the current model-centric enterprise architectures currently being employed (platforms, tools, stakeholders, users,maintenance etc)	X	X
		2. Identify the data and physical security requirements to allow secure information interchange between enterprise elements	X	
		3. Develop a concept of operations of how model and data information exhange would be accomplished.	X	
	Objective 2: Improve ability to share information	1. Identify IT infrastructure issues (firewalls, authentification, tool centers, support services, etc) that need to be addressed to improve the ability to share information	X	X
		2. determine how to enhance communication among stakeholders and users -- common vision/goals	x	X
		3. Identify and resolve issues regarding export control and compartmentalization of data		X
		4. Identify methodologies for model transformations		X
		5. Identify data objects and attributes needed for proper interoperability		X
	Objective 3: Adopt a architecture framework	1. Develop and execute a architecture framework for the standardization and facilitation of data exchange		X
		2. Negotiate and establish standard ontologies	X	X
		3. Identify the governance…	X	X
		4. Identify how versioning will be govenered and accomplished across the agency for common tools		X
	Objective 4: Perform pilots and case studies of integrated MBSE.	1. Identify pilots that are already being done	X	X
		2. Identify the need for new pilots of key areas of risk	X	X
		3. Identify opportunities for collaboration/guidance		X

Tasks for each Goal/Objective (Cont'd)

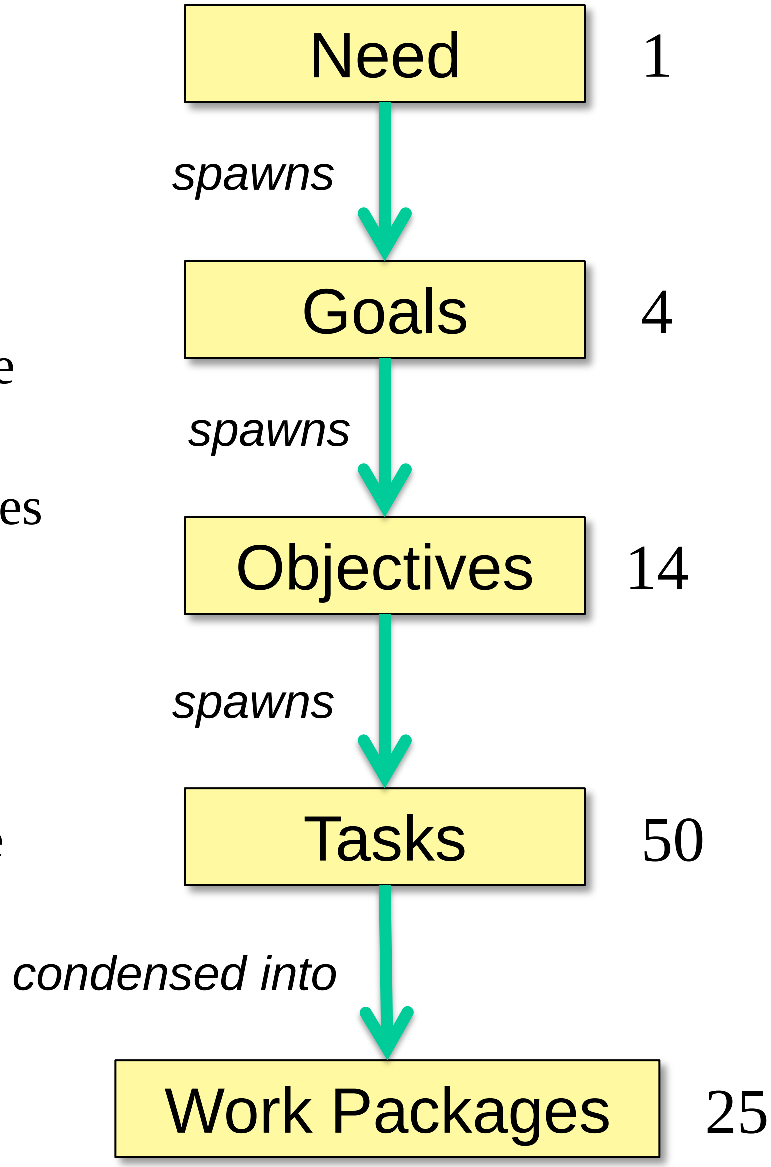
Goals	Objectives	Tasks/Initiatives	FY11 Task	FY12 Task
Goal 3: Inform/train invigorate workforce on model-centric architecture	Objective 1: Identify workforce resources and gaps of qualified personnel	1. Determine what capabilities are needed to enact model-centeric architectures at NASA	X	
		2. Determine current workforce with the identified needed capability		x
		3. Perform gap analysis and develop plan for resolving.		x
	Objective 2: Training	1. Determine what training is needed for both in-depth and awareness training	X	X
		2. Develop training plan on how to execute the identified needed training		X
		3. Execute training plan	X	x
	Objective 3: Communication	1. Develop a Communication Plan on how to get awareness of the Model-centric cultural change	X	X
		2. Execute plan	X	X
	Objective 4: Benchmarking	1. Identify program/projects, NASA organizations, industry, academia organizations that have used model-centric approaches and perform benchmarking	X	X
		2. Develop a benchmarking/lessons learned report and incorporate results into the Model-Centric planning/execution efforts	X	X

Tasks for each Goal/Objective (Cont'd)

Goals	Objectives	Tasks/Initiatives	FY11 Task	FY12 Task
Goal 4: Improve product quality and success through use of a model-centric architecture	Objective 1: Establish architectural	1. Develop a standard ontology for the enterprise	X	X
		2. Develop any necessary standards to enable model-centric efforts		X
	Objective 2: Establish best practices/methodology	1. Develop a best practice/method for using model-centric techniques for design reviews		X
		2. Develop best practice/methods for enhancing CM, change traceability, and version controls.		X
		3. Determine best practice/method for using model-centric techniques for early identification of gaps and issues relative to integration		X
		3. Determine best practice/method for using model-centric techniques for testing and verifications/validations.		X
		4. Determine best practice/method for the translation from design to manufacturing		X
		5. Determine what is needed to enable dmaximun reuse of successful designs		X
		6. Determine overal concept of operations for the maturing of models throughout lifecycle.		X
	Objective 3: Enable greater insight/visibility into the product	1. Determine effective way to enable knowledge sharing and lessons learned within and across projects	x	X
		2. Determine techniques for enabling instant access to data to eliminate uncertainties.		X
		3. Determine techniques for demonstrating/communicating successes with model-centric methodologies.		X

Development of Work Packages

- These objectives were subsequently renumbered from 1 to 50 and then analyzed for overlaps and completeness
- As a result 25 "Work Packages" were generated that encompasses all the identified work – each are still tied to the NGOs (See trace chart)
- These work packages will be the activities that need to be performed to accomplish the work to start moving the agency towards a Model-centric architecture
- Leads will be assigned to each work package who will then develop the more detailed schedules with identified milestones and products



Draft Work Packages

Work Packages	Description	FY11 Task	FY12 Task
1. Conduct a cost/benefit analysis for implementing model-centric architecture across the NASA enterprise	a. Perform benchmarking of at least 10 organizations comprised of : NASA Centers, industry, other government agencies. B. Perform an analysis of the resulting data to determine if this effort would be cost-effective to implement at a NASA enterprise level. c. Document the findings suitable for distribution and briefings d. Report results to the EMB and other senior executive forums as requested. e. Incorporate the lessons learned into the model-centric development activities and the knowledge sharing system	X	X
2. Determine what type of metrics/audits are needed to capture, monitor, control and understand life cycle costs	a. Determine what kind of metrics are currenly being used successfully used for understanding LCC b. Determine what other metrics would be useful c. Determine complete set of metrics that the model-centric architecture will need to capture and document. d. Work with Model-centric architecture design team to ensure the incorporation of these metrics		X
3. Determine how to enable better cost and schedule estimation through the use of a model-centric architecture	a. Understand successes and failures of current methods of performing cost and schedule estimations b. Develop a methodology for improving cost and schedule estimations using a model-centric archtitecture. c. Pilot technique to ensure feasibilitly d. Document resulting technique e. Determin what personnel will need to be trained on this technique f. Communicate techniques to appropriate personnel		X

Draft Work Packages (Cont'd)

Work Packages	Description	FY11 Task	FY12 Task
4. Determine methodologies to reduce the cost of translating conceptual designs into the manufacturing of products (Design-to-Manufacturing)	a. Understand successes and failures of current methods of performing design-to-manufacturing (DTM) across the agency b. Develop a methodology for improving DTM using a model-centric archtitecture. c. Pilot technique to ensure feasibilitly d. Document resulting technique e. Determin what personnel will need to be trained on this technique f. Communicate techniques to appropriate personnel		X
5. Determine what is needed to enable design and interface issues to be identified/analyzed earlier	a. Understand current practices b. Develcp a methodology for improving practices using a model-centric architecture. C. Pilot techniques d. Document resulting technique e. Determine what personnel will need to be trained on this technique f. Communicate/train techniques to appropriate personnel		X
6. Develop techniques that will allow a more efficient workflow and use of the enterprise workforce	a. Understand current practices b. Develop a methodology for improving the efficiency of the workforce and reduction of design iterations through use of workflows to enact the SE Practices of NPR 7123.1, PM practices of NPR 7120.5, and other NPRs as appropriate C. Pilot techniques d. Document resulting technique e. Determine what personnel will need to be trained on this technique f. Communicate/train techniques to appropriate personnel		X

Draft Work Packages (Cont'd)

Work Packages	Description	FY11 Task	FY12 Task
7. Determine techniques for authoritative source idendification and use by the enterprise.	a. Understand current practices b. Develop a methodology for improving practices using a model-centric architecture. c. Pilot techniques d. Document resulting technique e. Determine what personnel will need to be trained on this technique f. Communicate/train techniques to appropriate personnel		X
8. Determine methodologies for the reuse of models and information exchange between models	a. Understand current practices b. Develop a methodology for improving practices using a model-centric architecture. C. Pilot techniques d. Document resulting technique e. Determine what personnel will need to be trained on this technique f. Communicate/train techniques to appropriate personnel	X	X
9. Determine methodologies to ensure data integrity, content and flow between internal and external NASA enterprise elements.	a. Understand requirements and current practices of data integrity including storage, security, export control issues, and accessability. b. Develop a methodology for improving practices using a model-centric architecture. c. Pilot techniques d. Document resulting technique e. Determine what personnel will need to be trained on this technique f. Communicate/train techniques to appropriate personnel	X	X

Draft Work Packages (Cont'd)

Work Packages	Description	FY11 Task	FY12 Task
10. Determine methodologies that will allow more efficient/effective use of test time.	a. Understand current practices of performing testing (whetether developmental testing or for verification and/or validation) b. Develop a methodology for improving practices using a model-centric architecture. C. Pilot techniques d. Document resulting technique e. Determine what personnel will need to be trained on this technique f. Communicate/train techniques to appropriate personnel		X
11. Determine techniques that will allow effective accessibility to information about each part within a system	a. Understand current practices of how projects develop a Product Breakdown Structure and ability to attach information such as analysis results, testing results, and product information to each part. b. Develop a methodology for improving practices using a model-centric architecture. C. Pilot techniques d. Document resulting technique e. Determine what personnel will need to be trained on this technique f. Communicate/train techniques to appropriate personnel		X
12. Determine the current model-centric enterprise architectures currently being employed (platforms, tools, stakeholders, users,maintenance etc)	a. Understand current practices b. Develop a methodology for improving practices using a model-centric architecture. C. Pilot techniques d. Document resulting technique e. Determine what personnel will need to be trained on this technique f. Communicate/train techniques to appropriate personnel	X	X

Draft Work Packages (Cont'd)

Work Packages	Description	FY11 Task	FY12 Task
13. Develop a concept of operations of how model and data information exhange would be accomplished.	a. Understand current practices b. Develop a methodology for improving practices using a model-centric architecture. C. Pilot techniques d. Document resulting technique e. Determine what personnel will need to be trained on this technique f. Communicate/train techniques to appropriate personnel	X	X
14. Identify IT infrastructure issues (firewalls, authentification, tool centers, support services, etc) that need to be addressed to improve the ability to share information	a. Understand current IT infrasturcture that can be used to support model-centric architectures including platforms, tools, firewalls, and support services. b. Determine what IT infrastructure will be needed (future state) to fully support a model-centric architecture c. Perform a gap analysis d. Develop a plan (including cost and schedule)for filling the gaps and obtain approvals e. Execute Plan	X	X
15. Develop a Communication Plan for enhancing awareness, buy-in, approvals,	a. Determine who are the key stakeholders for establishing a model-centric culture b. For each stakeholder determine what their expectations are and what they would define as "success" (Measure of Effectiveness) c. Develop a Communications Plan as to how best to communicate and affect this culture change and obtain approvals, including communicating success, lessons learned and knowledge capture. d. Execute Communication Plan	X	X

Draft Work Packages (Cont'd)

Work Packages	Description	FY11 Task	FY12 Task
16. Develop methodologies for the exchange of models including necessary attributes and transformations	a. Understand current practices b. Develop a methodology for improving practices using a model-centric architecture. C. Pilot techniques d. Document resulting technique e. Determine what personnel will need to be trained on this technique f. Communicate/train techniques to appropriate personnel		X
17. Develop and execute a architecture framework for the standardization and facilitation of data exchange including ontologies and governance	a. Understand current architecture frameworks being used across NASA b. Determine the framework needed to implement model-centric architectures including ontologies and governance c. Perform a gap analysis d. Develop a plan (including cost and schedule)for filling the gaps and obtain approvals e. Execute Plan	X	X
18. Identify how versioning will be govenered and accomplished across the agency for common tools	a. Determine how versioning is currently being done across the centers b. Determine the best method of how to keep synchronized versions of common-use tools necessary to accomplish an agency model-centric architecture c. Domcument the plan and gain approvals d. Execute the plan		X

Draft Work Packages (Cont'd)

Work Packages	Description	FY11 Task	FY12 Task
19. Identify pilots that need to be performed in addition to existing pilots and those specifically associated with a Work Package	a. Determine what pilots are currently being independently done by centers b. Determine what pilots are in work or in planning stages for this model-centric effort c. Looking at various viewpoints such as across lifecycles and across functions, determine any additional pilots that may be necessary to enable model-centric culture. d. Develop a plan including Center participation, external org participation, cost and schedule and gain approvals e. Execute plans incorporating them into the implementation plans of this effort	X	X
20. Develop and execute a plan to ensure the needed worforce capabilities to perform in a model-centric culture	a. Determine what capabilites are needed to enact odel-centric architectures b. Determine current workforce with the needed capabilities c. Perform gap analysis d. Develop a plan (to include a training plan for for both indepth and awareness training as well as hires) for resolving gaps and gain approvals . e. Execute plan	X	X
21. Develop any necessary standards to enable model-centric efforts	a. Understand current standards that exist within NASA, centers, industry and other organizations that enable a model-centric archtiectures b. Identify new standards that will be required c. Develop plan for the generation of the necessary standards (includes center participation, cost and schedule) d. Execute plans		X

Draft Work Packages (Cont'd)

Work Packages	Description	FY11 Task	FY12 Task
22. Develop a best practice/method for using model-centric techniques for milestone reviews	a. Understand current practices for performing milestone reviews and associated entrance/success criteria per NPR 7123.1 b. Develop a methodology for improving practices using a model-centric architecture. C. Pilot techniques d. Document resulting technique e. Determine what personnel will need to be trained on this technique f. Communicate/train techniques to appropriate personnel		X
23. Develop best practice/methods for enhancing CM, including change traceability, and version controls.	a. Understand current practices for conducting CM b. Develop a methodology for improving CM practices using a model-centric architecture. C. Pilot techniques d. Document resulting technique e. Determine what personnel will need to be trained on this technique f. Communicate/train techniques to appropriate personnel		X
24. Determine what is needed to enable maximun reuse of successful designs including parts and object oriented libraries.	a. Understand current practices for reuse b. Develop a methodology for improving practices using a model-centric architecture. C. Pilot techniques d. Document resulting technique e. Determine what personnel will need to be trained on this technique f. Communicate/train techniques to appropriate personnel		X

Draft Work Packages (Cont'd)

Work Packages	Description	FY11 Task	FY12 Task
25. Determine techniques for enabling instant access to data to eliminate uncertainties.	a. Understand current practices b. Develop a methodology for improving practices using a model-centric architecture. C. Pilot techniques d. Document resulting technique e. Determine what personnel will need to be trained on this technique f. Communicate/train techniques to appropriate personnel		X

Work Package Leads

- The following groups are tentatively designated as "Leads" for these work packages.
  - Centers and other orgs are expected to provide support as desired and should get with the designated POC

Leads	Integration Team	MBSE	PDLM	M&S	CAD
POC	Linda K. Bromley	Stephen J. Kapurch & Dennis W. Rohn	Harvey L. Schabes & Maninderpal S. Gill (Paul)	James E. Adams (Jamie)	Hanh X. Nguyen & Christy L. Herring
Work Package Numbers	1, 2, 3,10, 13, 15, 17, 19, 20	5, 6, 21, 22, 24	7, 9, 11, 12, 14, 23, 25	8, 16	4, 18

Work Package to NGO Traceability

	Goal 1			Goal 2				Goal 3				Goal 4		
Work Packages	O1	O2	O3	O1	O2	O3	O4	O1	O2	O3	O4	O1	O2	O3
1. Conduct a cost/benefit analysis for implementing model-centric architecture across the NASA enterprise	√										√			
2. Determine what type of metrics/audits are needed to capture, monitor, control and understand life cycle costs	√													
3. Determine how to enable better cost and schedule estimation through the use of a model-centric architecture	√													
4. Determine methodologies to reduce the cost of translating conceptual designs into the manufacturing of products (Design-to-Manufacturing)	√												√	
5. Determine what is needed to enable design and interface issues to be identified/analyzed earlier	√												√	
6. Develop techniques that will allow a more efficient workflow and use of the enterprise workforce	√	√	√											
7. Determine techniques for authoritative source idendification and use by the enterprise.		√												
8. Determine methodologies for the reuse of models and information exchange between models		√		√										
9. Determine methodologies to ensure data integrity, content and flow between internal and external NASA enterprise elements.		√		√	√									
10. Determine methodologies that will allow more efficient/effective use of test time.			√										√	
11. Determine techniques that will allow effective accessibility to information about each part within a system			√											
12. Determine the current model-centric enterprise architectures currently being employed (platforms, tools, stakeholders, users,maintenance etc)				√										
13. Develop a concept of operations of how model and data information exhange would be accomplished.				√									√	
14. Identify IT infrastructure issues (firewalls, authentification, tool centers, support services, etc) that need to be addressed to improve the ability to share information					√									
15. Develop a Communication Plan for enhancing awareness, buy-in, approvals,					√					√				√
16. Develop methodologies for the exchange of models including necessary attributes and transformations					√									
17. Develop and execute a architecture framework for the standardization and facilitation of data exchange including ontologies and governance						√						√		
18. Identify how versioning will be govenered and accomplished across the agency for common tools						√								
19. Identify pilots that need to be performed in addition to existing pilots and those specifically associated with a Work Package							√							
20. Develop and execute a plan to ensure the needed worforce capabilities to perform in a model-centric culture								√	√					
21. Develop any necessary standards to enable model-centric efforts												√		
22. Develop a best practice/method for using model-centric techniques for milestone reviews													√	
23. Develop best practice/methods for enhancing CM, including change traceability, and version controls.													√	
24. Determine what is needed to enable maximun reuse of successful designs including parts and object oriented libraries.													√	
25. Determine techniques for enabling instant access to data to eliminate uncertainties.														√

Model-Centric Activities by Center

ARC Examples

- Working to integrate MBSE data and models for the new programs across organizations (level 1, programs) and applications (Cradle, Enterprise Architect, etc.) in order to provide an automatically generated, up to date Integrated Functional Analysis (IFA) Report based on data from authoritative sources.
- Developing production integration between International Space Station data sets in order improve data integrity.
  - Integration supports creating dynamic digital links from Hardware Parts and Drawings stored in Vehicle Master Database (VMDB) to associated Problems (PRACAs) and Failure Modes Effects Analyses (FMEAs) associated with those parts.
  - Historical data sets show that PRACAs and FMEAS have data entry errors or missing data for associated part information.

DRFC Examples

- **Apply MBSE as a pilot on the UAS in NAS project to investigate the views/framework required for adequately representing an ADS-B system for development.**
  - Initial plans will be presented in January 2012, and a report and associated presentation charts describing the views/framework and lessons learned will be presented in August 2012.
  - **MBSE Models will include development of mission operational (OV) views and systems views (SV) and conceptual visual display.**
    - ADS-B is a next generation surveillance technology incorporating both air and ground aspects that provide air traffic control (ATC) with a more accurate picture of the aircraft's three-dimensional position in the en route, terminal, approach and surface environments.
    - The aircraft provides the airborne portion in the form of a broadcast of its identification, position, altitude, velocity, and other information. (Ronald Ray)

GRC Examples

- Have been investigating the approach to typical milestone review artifacts when using MBSE
  - Using a partial model of a project (LaRC's On-Board Data Networking (OND) project), produce typical artifacts for an early milestone review from a MBSE standpoint
    - MCR
      - Mission Goals and Objectives
      - Concept of Operations
    - SRR
      - Requirements "documents"
      - "documentation tree"
      - Requirements Allocation

JSC Usage

- JSC is a heavy user of Models and Simulations for engineering analysis, human systems integration, training and visualizations
- Use of CAD is ubiquitous, are beginning to consider the 3D models as the master from which the 2D drawings are generated.
- Just beginning to explore the use of MBSE tools to tie all aspects of a project together and to determine effects of changes to one part of a system on another.
- Looking at using more aspects of a PDLM system to archive and organize data files and information
- Integrating everything is the holy grail for future activities.

JSC Examples

- AES MMSEV (Multi-Mission Space Exploration Vehicle) will use Model based system engineering techniques to define system characteristics and support integration analysis and performance characterization.
  - Modeling enables evaluation of new technologies within an existing infrastructure.
  - Integrated Power Avionics and Software facility is designed to enable early hardware/software integration for technology development and evaluation.
  - Model based system engineering techniques will be used to define system characteristics and support integration analysis and performance characterization.
  - Modeling enables evaluation of new technologies within an existing infrastructure.
  - System models will be used directly to support test orchestration via ATML
  - Demonstration of initial effort provided to JSC/EA management completed in September
- EV7 is in the process of developing a system model of the Orion Avionics Subsystem.
  - The system model will include operational, functional and physical models that capture the core mission DRM.
  - The next step is to link system requirements to the operational, functional, and physical driving and constraining requirements of the core DRM.

JSC Examples (Cont'd)

- The JSC Digital Design through Manufacturing (DDTM) effort includes a preliminary pilot prior to full-scale operations.
  - DDTM is a process which encapsulates digital Product Definition data from early concept through the manufacturing phase, providing each downstream data consumer with a complete package of authoritative, up-to-date engineering data via electronic tools and processes.
  - The objective of DDTM is to reduce cycle time, improve quality and reduce costs by streamlining the product development process.
  - DDTM integrates processes, tools, data, and people from engineering through production
  - Complete geometric and product definition, along with key design and process characteristic are captured in the 3D master model and corresponding engineering data which has historically been provided through a 2D Drawing.
  - Loss of funds for this effort has put future activity on hold.
    - Was approaching CDR and had already begun developing some key components for the effort
- MBSE is being used to ensure that JSC/MOD and flight software pre-flight production processes, along with Program requirements, are integrated using the latest systems engineering methodologies in order to put in place an efficient and effective operations capability including processes and systems required to support the operations.

JSC Examples (Cont'd)

- Project Morpheus:
  - Implemented a model-based approach to requirements development.
    - Began with a detailed set of operational models in Cradle and then did a flow-down to requirements within the same tool.
    - Also did a flow-down of needs, goals and objectives to the requirements within the same environment.
  - During the project lifecycle the requirements management was moved from Cradle to SharePoint.
    - SharePoint has been used across the entire project lifecycle for project management and systems engineering data, communication and collaboration.
    - One of the advantages of SharePoint for PM/SE&I is the rapid development of online "databases" that can be used to capture everything from actions and decisions to the master equipment list and test logs.
    - These databases, called "lists," can be cross-linked to each other; every data item can have an owner, as well as version history.
    - The integration of the databases was a means for capturing interface data, and securing agreements between subsystems on specific commodities (power, data, thermal, etc).
    - The use of SharePoint has significantly reduced the amount of formal documentation and has enabled most data to be viewed by the team in its "native environment."

JSC Examples (Cont'd)

- SysML to ATML usage
  - To demonstrate a path to the goal of entering data one time during a Program, this effort is attempting to show that details ranging from interface descriptions to functional requirements can be derived from SysML into an Automated Test Markup Language (IEEE 1671, ATML) format.
  - It may be possible to use SysML Use Case, Activity, Requirement, Block Definition, and other diagrams to schedule equipment and identify missing "glue" components during planning, to configure connections and equipment during a test, and produce low-cost heavily-detailed documentation products.
  - Using the JSC Integrated Power and Avionics Systems (IPAS) testbed as pathfinder
- Human Factors has been doing or have done the following human performance related M&S related activities:
  - (1) Human Task Discrete Event Modeling and Simulation;
  - (2) Light Source Modeling and Simulation;
  - (3) Acoustic Modeling and Simulation;
  - (4) Anthropometric Modeling and Simulation

JPL Examples

- <u>IMCE (Integrated Model Centric Engineering)</u>
  - This initiative is headed up by JPL's systems engineering organization but encompasses all other engineering organizations. That link is particularly strong to mechanical engineering.
  - The initiative's mission is to advance from our current document-centric engineering practices to one in which structural, behavioral, physics and simulation-based models representing the technical designs are integrated and evolve throughout the life-cycle, supporting trade studies, design verification, and system V&V
- <u>D2D (Design to Delivery)</u>
  - The objectives of this initiative are more efficient
    - production/acquisition planning, tracking, and execution
    - management of product data
    - information for decision making
  - This initiative is managed from within JPL's Engineering and Science Directorate (Steve Flanagan) in collaboration with JPL's OCIO

JPL Examples (Cont'd)

- <u>Visual Information Browser</u>
  - JPL's mechanical systems organization (part of the Engineering and Science Directorate) is currently setting out to collaborate with our core CAD and PDM vendor in the development of a product information 'browser' based on a visual representation of the product using its CAD model and an associated MS Excel – like information management tool.
  - The goal is to provide key product information over its development lifecycle.
  - This information currently resides in isolated repositories and is difficult to find, integrate and visualize.
  - By accessing as needed information via a visual user interface this planned activity will vastly simplify status reporting and decision support.
  - But the most significant impact will be on concurrent design and review, when all product information is accessible and viewable in a dynamic way.

JPL Examples (Cont'd)

- Developed training modules
  - Module 1: "Systems Engineering with Models " (2 hours)
  - Module 2: "Introduction to Modeling" (2 hours)
  - Module 3 in work: Developing and Working with Models (4 Hours)

KSC Examples

- Digital Collaborative Environment (DCE)
  - Demonstrates a real-time data centric approach to integrating multiple organizations/participants in a collaborative environment using commercial off the shelf (COTS) tools while applying standards and interoperability constraints
  - Demonstrates ability to utilize various Agency and Industry available COTS tools by linking the information between them and improving workflow efficiency, communication, and data accuracy [Requirements Management (RM) tools (e.g. Cradle, TCSE, DOORS); and Product Data Management (PDM) tools (e.g. Windchill & TCUA)]
  - Demonstrates ability to link associated multi-level requirements, 3D CAD model representations, and their product structures - providing visibility and access to different data levels contained in distributed systems associated with a multi-level customer / supplier environment (Windchill, Pro-E, Cradle, TCSE, & TCUA integrated to date)
  - Provides a foundation for additional NPR 7120.5/.9 & NPR 7123.1 implementation development in the follow-on Pathfinder for processes, toolsets, and standards culminating in data centric processes, DRDs, and contractual clauses for 21stC GSP and NASA

KSC Examples (Cont'd)

- KSC Enterprise Information Architecture Objectives (include):
  - Interoperability among KSC and partner information systems by promoting data structures and data exchanges that are based on a common understanding of data
  - Exposure of data standards to the broader KSC community and seek collaborative input from that community on how shared data is best defined and structured
  - Provide data exchange standards that are based on standardized data and reliable information

LaRC Examples

- Developed models for the Onboard Data Network (ODN) task providing
  - System model documentation: reference mission, target technology, and MBSE processes and techniques.
  - Systems engineering products: stakeholder expectations, concept of operations, requirements documents, system specification
  - Reporting tools: document templates
  - Training materials based upon the above model and the work performed to create the model
    - Includes models, lessons learned, and how to’s
  - Report describing what and how we performed the pilot activities
- Will apply techniques and expand usage for the MISSE-X

MSFC Examples

- As part of a lead approach will be the usage of model-centric techniques shifting the focus from a document centric to a data centric culture through the use of a suite of tools to help form the data architecture on SLS (Selection of CRADLE for Requirements management, use of Windchill 10.0 for CM, Active Risk Manager, SharePoint, etc)
- Developing an SLS Vehicle Functional Analysis Model to enable work through functional design space and tightly couple ConOps, requirements and design through the functions that drive them.
  - Used more as an analysis tool at this point to identify where we have gaps/issues with design products.
  - Working to link this to the functional models that the Vehicle Management Team is using for GNC and Vehicle System Manager.
  - Through SYSML version of EA, continuing Vehicle System Manager Modeling, GNC and the Functional modeling. This approach will allow better connection with the FSW development.
  - Continuing Model Based Design Principles with the use of Interface Control Models
  - Using Cradle on SLS and developing functional block diagrams

MSFC Examples (Cont'd)

- Ares I Upper Stage As-Designed As-Built - Design and Data Management System (DDMS) Interconnection with Boeing's IGOLD. Supports manufacture and assembly of Ares I components to minimize use of manual labor transferring files and associated engineering changes between NASA design and Boeing simulation and manufacturing.
- Support to Altair requirements development and design capabilities definition. Refined Altair OpsCon to capture detailed tasks, evaluated flow of functions to support the tasks and confirmed vehicle architecture could meet those functions. Also used to derive functional requirements and to decompose to performance values and allocate to hardware

SSC Examples

- DDMS/Windchill development and sustainment
- Development of test facility models and incorporation into the DDMS environment
- Pilot To Integrate Propulsion Test Facility and CCDEV Engine Testing Requirements and Models

MBSE Implications for Projects

MBSE implications for projects

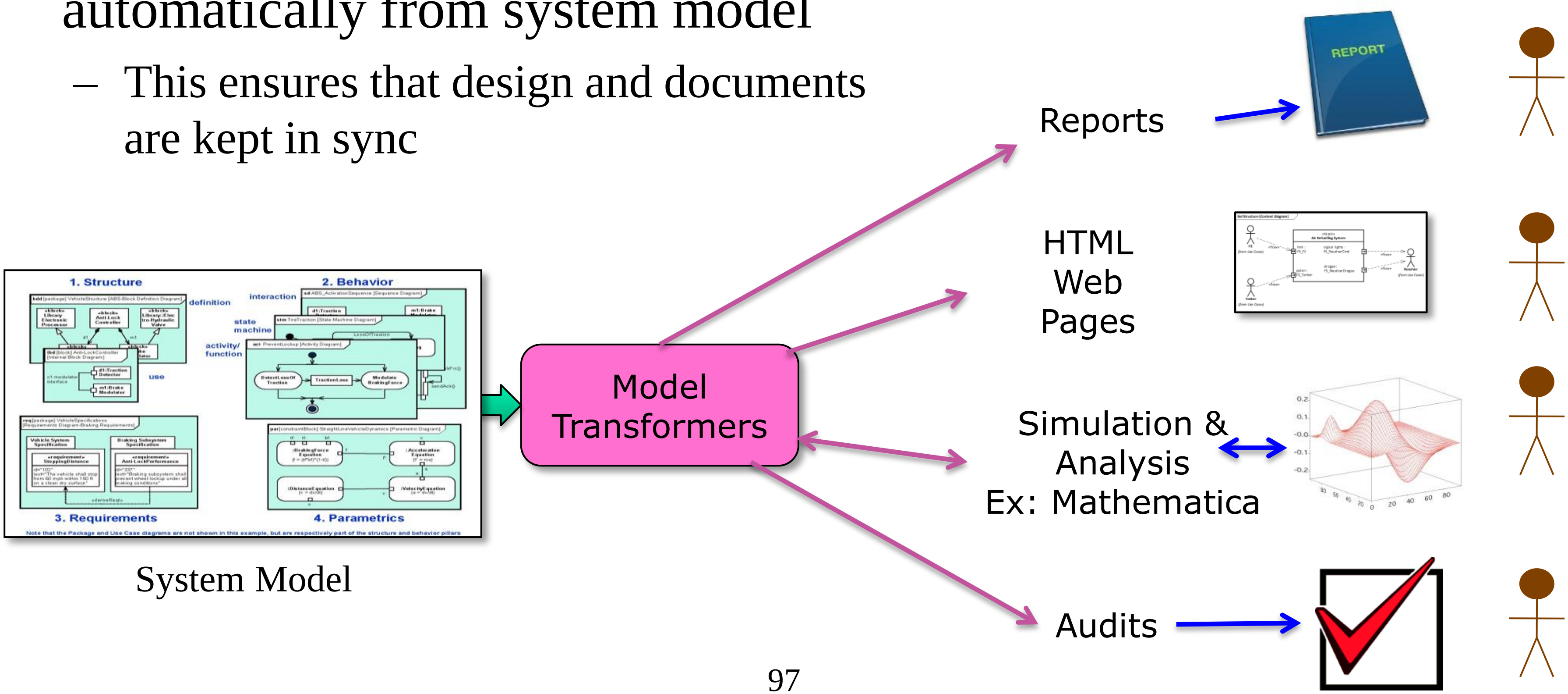
How does MBSE affect…

- **deliverables?**
- **project schedule/milestones?**
- **project organization?**
- **processes (e.g. design, reviews, CM, model mgmt, methodology…)?**
- **infrastructure?**
- **metrics?**

MBSE implications for projects (1 of 6)

How does MBSE affect deliverables?

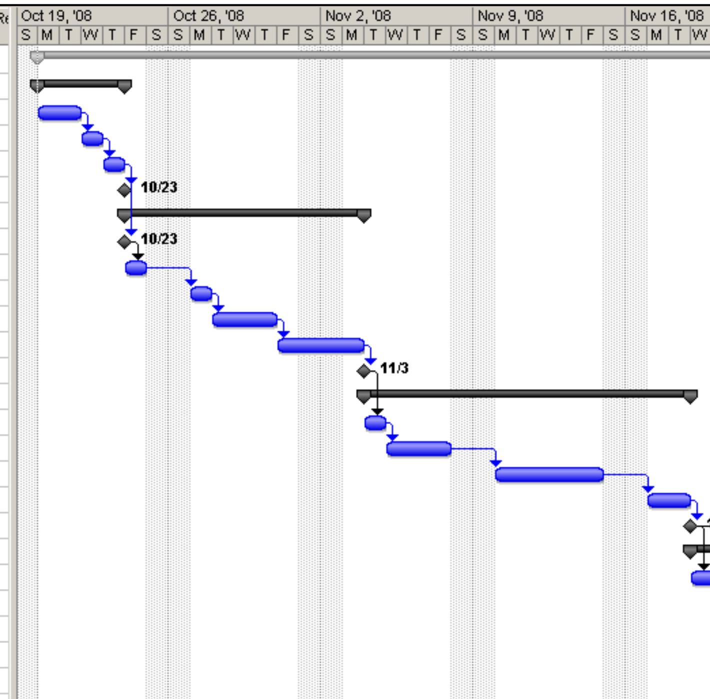
- Project still has to produce deliverables for each review
- Some documents may be generated automatically from system model
  - This ensures that design and documents are kept in sync



How does MBSE affect project schedule?

- Schedule time and resources to deploy infrastructure and train workforce
- Model development becomes infused within the schedule

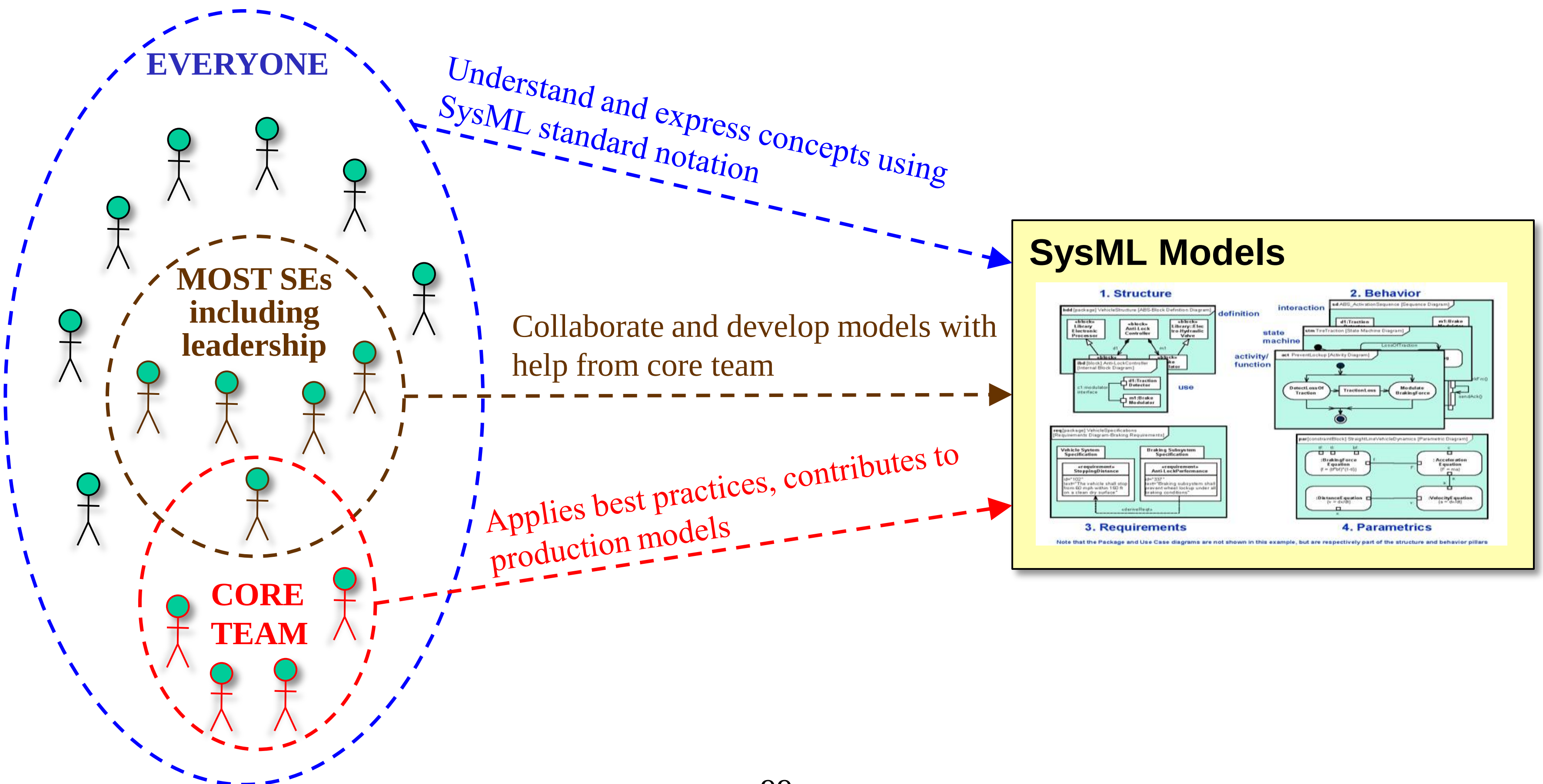
	Task Name	Duration	Start	Finish	Predecessors	Re
0	⊟ Project Server 2007 Implementation	29.25 days	on 10/20/08	Fri 11/28/08		
1	⊟ **Analysis and Design**	**4 days**	**Mon 10/20/08**	**Thu 10/23/08**		
2	Analysis and Design workshop	2 days	Mon 10/20/08	Tue 10/21/08		
3	Requirements document	1 day	Wed 10/22/08	Wed 10/22/08	2	
4	Review of the requirements	1 day	Thu 10/23/08	Thu 10/23/08	3	
5	Requirements document accepted	0 days	Thu 10/23/08	Thu 10/23/08	4	
6	⊟ **Installation**	**7 days**	**Thu 10/23/08**	**Mon 11/3/08**		
7	Send requirements	0 days	Thu 10/23/08	Thu 10/23/08	4	
8	Prerrequisite verification	1 day	Fri 10/24/08	Fri 10/24/08	7	
9	Project Server Installation	1 day	Mon 10/27/08	Mon 10/27/08	8	
10	Tests	3 days	Tue 10/28/08	Thu 10/30/08	9	
11	Installation Log	2 days	Fri 10/31/08	Mon 11/3/08	10	
12	Installation acceptance	0 days	Mon 11/3/08	Mon 11/3/08	11	
13	⊟ **Configuration**	**11 days**	**Tue 11/4/08**	**Tue 11/18/08**		
14	Security configuration	1 day	Tue 11/4/08	Tue 11/4/08	12	
15	Enterprise configuration	3 days	Wed 11/5/08	Fri 11/7/08	14	
16	Tests	5 days	Mon 11/10/08	Fri 11/14/08	15	
17	Configuration Log	2 days	Mon 11/17/08	Tue 11/18/08	16	
18	Configuration acceptance	0 days	Tue 11/18/08	Tue 11/18/08	17	
19	⊟ **Training**	**7.25 days**	**Wed 11/19/08**	**Fri 11/28/08**		
20	Project Manager's training	24 hrs	Wed 11/19/08	Fri 11/21/08	18	
21	Team Member's training	6 hrs	Mon 11/24/08	Mon 11/24/08	20	
22	Executive's training	4 hrs	Mon 11/24/08	Tue 11/25/08	21	
23	Project Server Administrator's training	24 hrs	Tue 11/25/08	Fri 11/28/08	22,18	
24	Go Live!	0 days	Fri 11/28/08	Fri 11/28/08	23	



MBSE implications for projects (3 of 6)

How does MBSE affect project organization?

- Everyone needs training, but not to the same depth
- Different levels of training for different levels of modeling

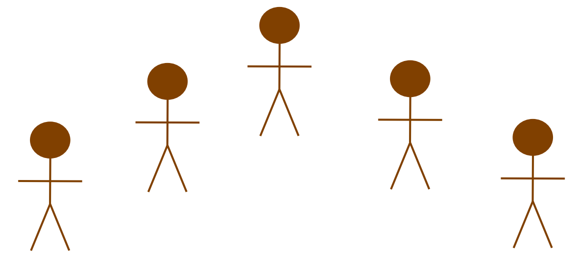


MBSE implications for projects (4 of 6)

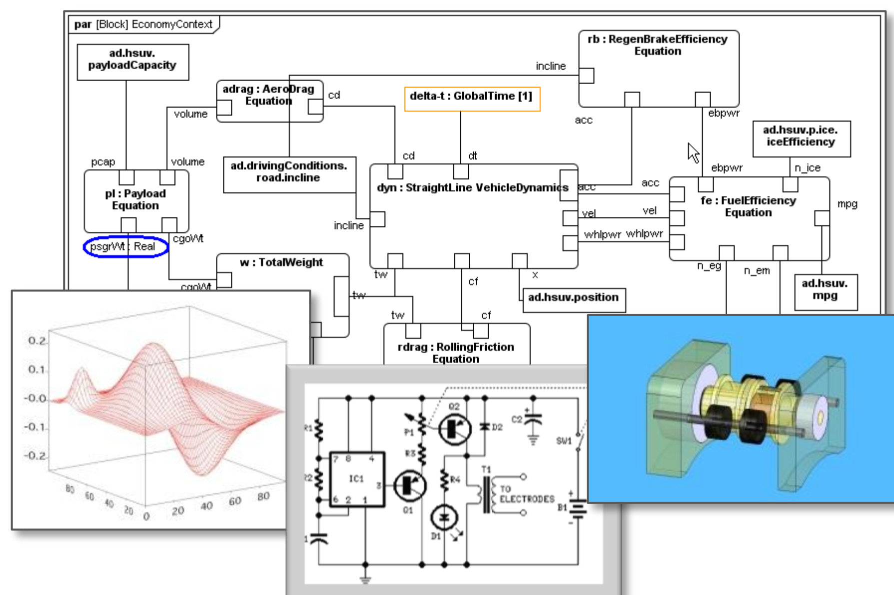
Does MBSE affect reviews?

- It *can*, but doesn't have to
- Leverage the model by reviewing *the model itself*
- Stakeholders focus on the views of the system model that address *their* concerns

Reviewers



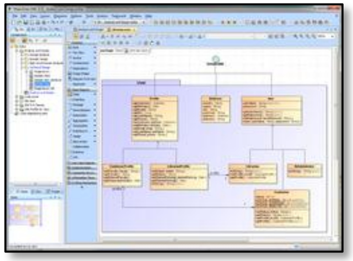
Models



MBSE implications for projects (5 of 6)

How does MBSE affect infrastructure?

- Need:
  - System modeling tool(s)
  - Training (in modeling and in tool usage)
  - Standards (modeling style guide, model management)
  - Methodology*



SysML Modeling Guide

IMCE Team
Version: 9/24/11

* See "Survey of Model-Based Systems Engineering (MBSE) Methodologies", J. A. Estefan, 2008, INCOSE.
http://www.omgsysml.org/MBSE_Methodology_Survey_RevA.pdf

MBSE implications for projects (6 of 6)

How does MBSE affect metrics?

- Easier to get data from models and update metrics
- Example metrics
  - Quality of design
    - Mass margin, power margin, data margin, cost, …
  - Progress of design and development effort
    - Completeness of component specs, # use case scenarios, …
  - Estimated effort to complete design and development
    - Constructive Systems Engineering Cost Model (COSYSMO) gets inputs from system model (# requirements, # use cases, etc.)
  - Others:
    - Number of critical TBDs
    - Stability of requirements and design changes over time
    - Potential defect rates