



Extension of MBSE for Project Programmatic Management on the Asteroid Redirect Robotic Mission

presenter: *Oleg Sindiy, PhD*

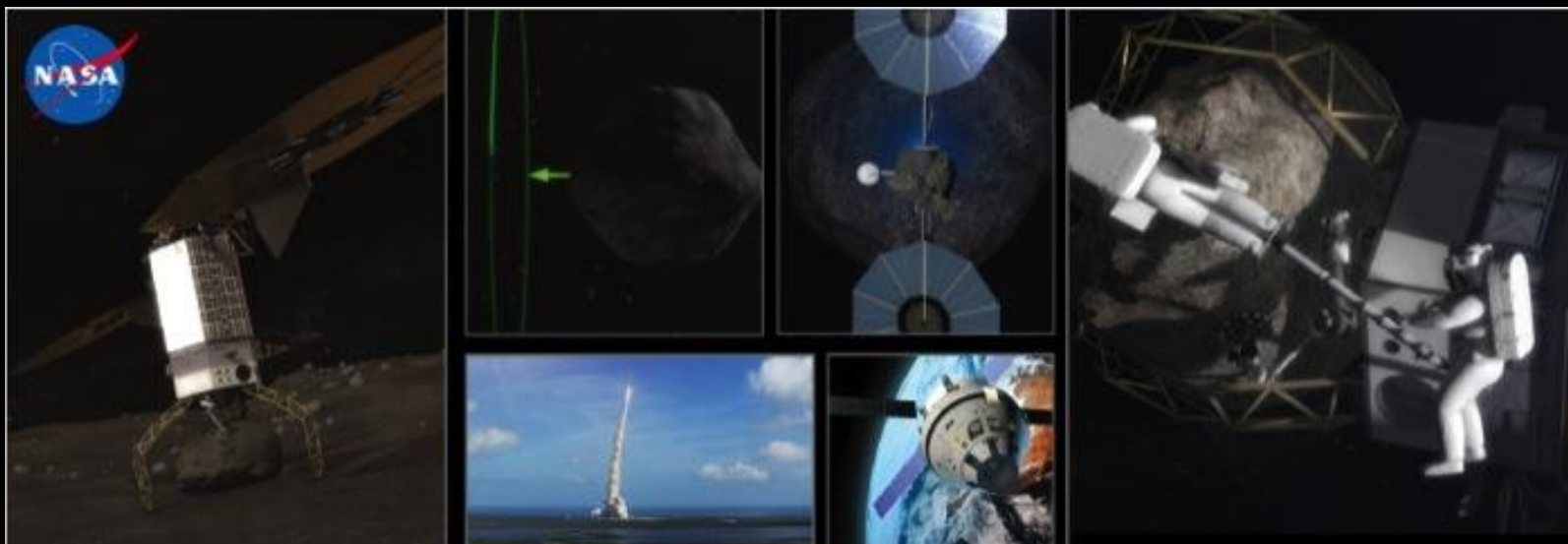
co-authors: *Brian Weatherspoon, Raffi Tikidjian, and Tanaz Mozafari*

Jet Propulsion Laboratory, California Institute of Technology

8 March 2017

2017 IEEE Aerospace Conference

Big Sky, MT



Agenda

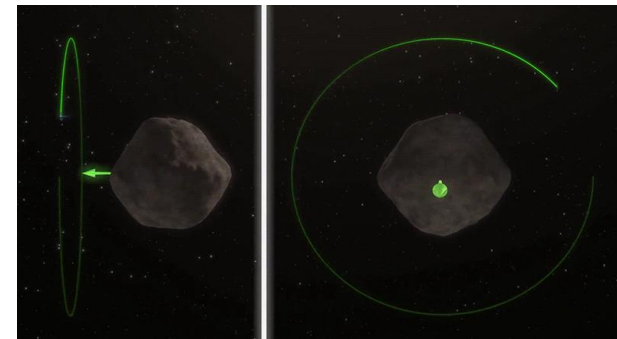
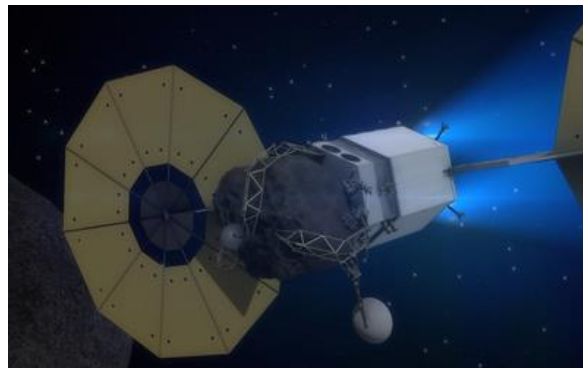
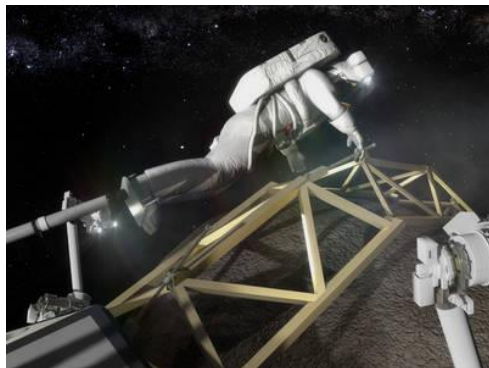
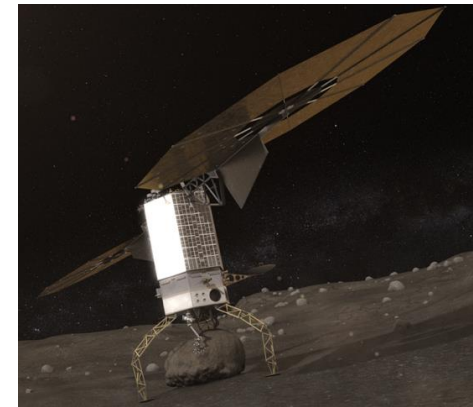
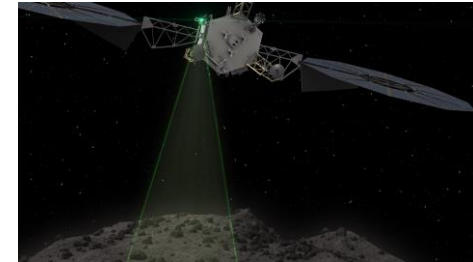


- Proposed Asteroid Redirect Robotic Mission (ARRM) Overview
- Model-based Systems Engineering (MBSE) on ARRM
 - Infrastructure: Environment & Processes
 - Summary of MBSE for Technical Architecture Development
- MBSE for Programmatic Management
 - Modeling Framework Features
 - Document Management
 - Document Metadata Definition
 - Personnel Metadata Definition
- Benefits Observed
- Conclusions & Future Work
- Acknowledgements

Proposed ARRM Overview



- currently in Phase B-preliminary design & technology development
- planned launch in early 2020's
- employ advanced Solar Electric Propulsion
- characterize (study) and land on an asteroid
- retrieve a multi-ton boulder
- demo a gravity tractor asteroid deflection maneuver
- return, with a boulder, to crew-accessible cis-lunar orbit
- rendezvous with ARCM's Orion capsule in mid-2020s
- support crew EVAs for boulder study & sample collection



MBSE on ARRM



- Need:
 - Info Management opportunity to support multi-organization, distributed team of stakeholders
 - Exploration of leaner implementation for proven NASA Systems Engineering (SE) processes
- ARRM ripe for a targeted application of MBSE:
 - MBSE pertains to “elevating models in the engineering process to a central and governing role in the specification, design, integration, validation, and operation of a system.”
 - single-source-of-truth for targeted set of data
- Formulated an MBSE approach:
 - Leverages System Modeling Language (SysML) to create a System Model
 - Secure & accessible modeling, task, risk, and project data management environment
 - Refined existing, but evolving, MBSE techniques for specific needs
 - Versatile reporting infrastructure from System Model content
- Products for successful program & project reviews (MCR, SRR-like, KDP-B):
 - technical: Mission Operational Concept, System Decomposition, Functional Requirements
 - linkage of documentation to technical content in System Model
 - programmatics tracking: project documentation, milestones, and personnel

MBSE Infrastructure: Environment & Processes



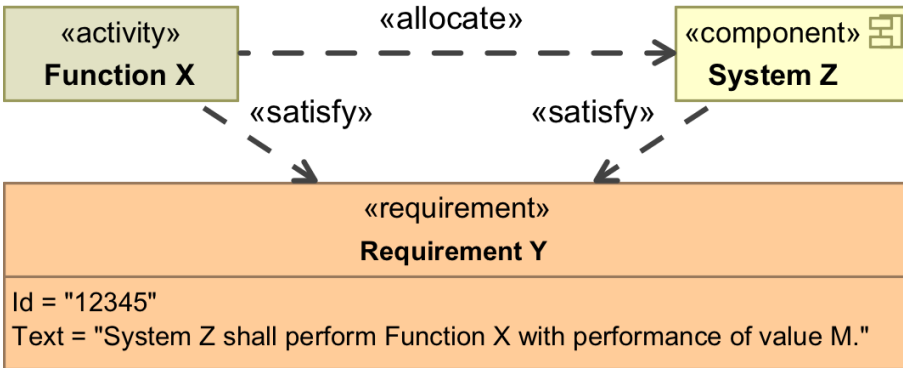
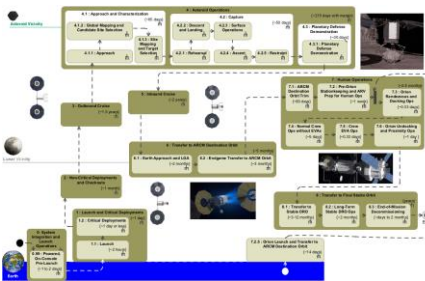
- secure cloud-based environment for modeling, task, risk & project data management environment
 - accessible by JPL and NASA team members
 - collaborative modeling server for System Model
 - web-based reporting from System Model (View Editor tool) w/ export to traditional reporting forms (pdfs, doc, csv)
 - web-based task tracking: SE tasks, MBSE capability development (including bug tracking)
 - info management: project portal, doc repository, wikis, chat & IM
- dedicated & regularly scheduled training sessions
 - all levels of stakeholders and experience
- inclusion of processes for configuration management & engineering change requests



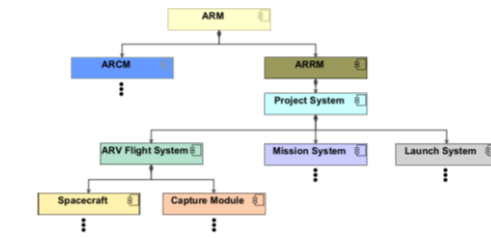
MBSE for ARRM Technical Architecture Development

Functional Requirements Validation: development & validation of technical requirements that map to activities & functions in mission operational concept as performed by mission systems

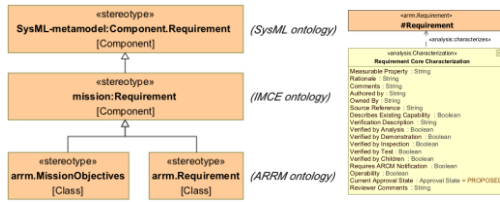
Mission Operational Concept Definition



System Decomposition & Characterization



Functional Requirements Development & Validation



Reference: Sindiy, O.V., Mozafari, T., and Budney C.J., “Application of Model-Based Systems Engineering for the Development of the Asteroid Redirect Robotic Mission,” *AIAA Space 2016 Conference*, Long Beach, CA, 13-16 September 2016. [AIAA 2016-5312](#).







MBSE for ARRM Programmatic Management



ARRM team leveraged MBSE capabilities to also manage project programmatic:

1. **document metadata** definition for use in document cover page generation and for tracking document ownership, approval & release state information
2. project metadata definition for use of **personnel role** descriptions & assignments
3. status of, including **release schedule** reporting with regards to project **milestones** and, access to latest in-work & approved documentation

A screenshot of the ARRM Project Dashboard. The title "ARRM Project Dashboard" is at the top left. Below it is the section header "Project Management" in bold blue text. The dashboard contains two columns of project management tools, each with an icon and a text label. The left column includes "Project Document List" (document icon), "Organizational Breakdown Structure (OBS)" (hierarchy icon), and "Project Schedule" (calendar icon). The right column includes "Project Personnel" (group of people icon), "Nomenclature and Glossary" (book icon), and "Project Presentation Elements Library" (screen icon).

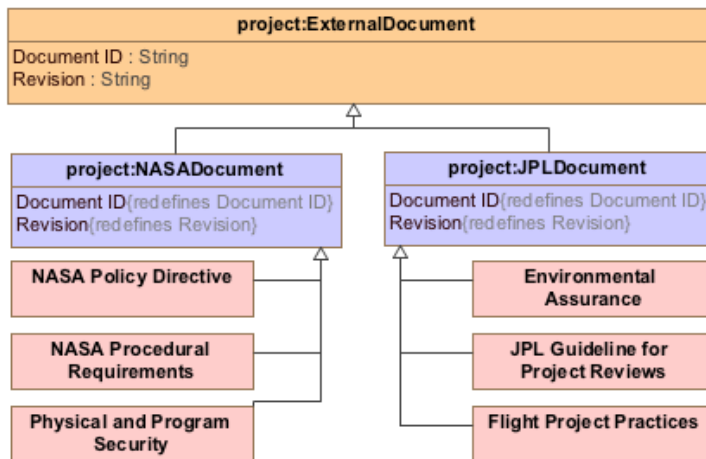
ARRM Project Dashboard	
Project Management	
 Project Document List	 Project Personnel
 Organizational Breakdown Structure (OBS)	 Nomenclature and Glossary
 Project Schedule	 Project Presentation Elements Library

Modeling Framework Features



Inheritance:

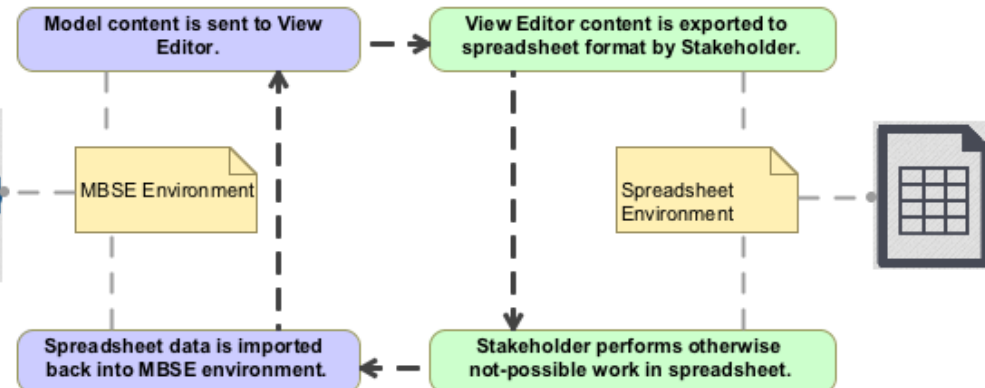
use of inheritance techniques to maintain conformity throughout modelling environment



Automation:

automation of daily tasks:

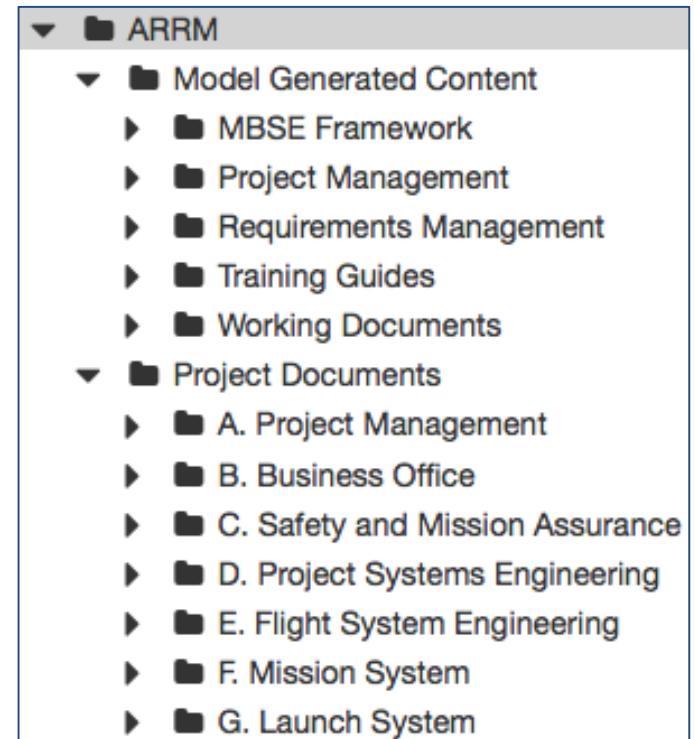
- project personnel data synchronization
- requirements data management
- data migrations between tools
- model/element maintenance
- [use of custom GUIs for above tasks]



Document Management (1 of 2)



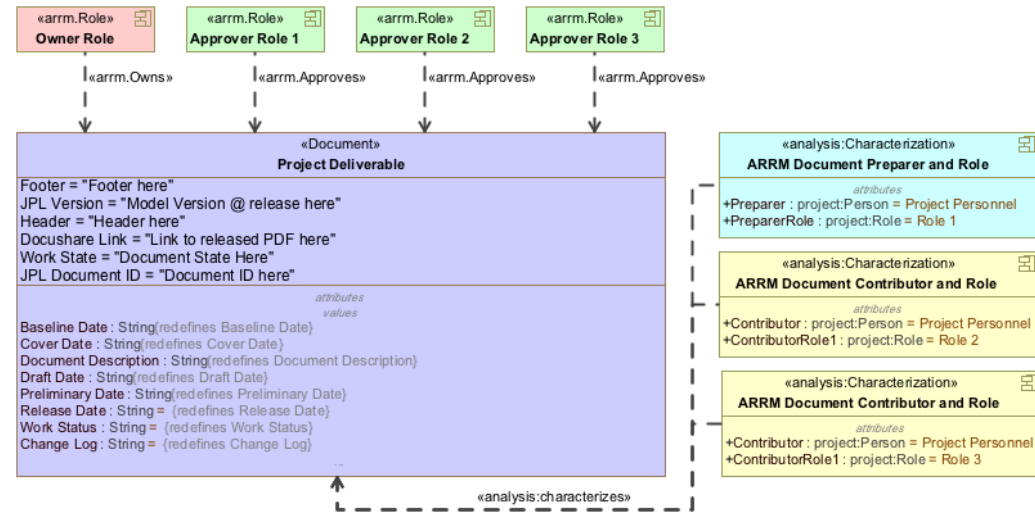
- project documentation is defined & managed in same MBSE-based environment as technical content
 - employs DocGen plugin in web-based View Editor environment
 - deployed a centralized project document list
 - doc titles (and other doc metadata) sections, tables, and diagrams are just another set of elements in larger System Model
 - both technical & programmatic content is integrated into documentation, which is generated and tracked in real-time



Document Management (2 of 2)



- documents linked to project milestones, phases & release schedule
- autonomous, uniform formatting of deliverables
- repository of applicable & reference documents
- formal document release process



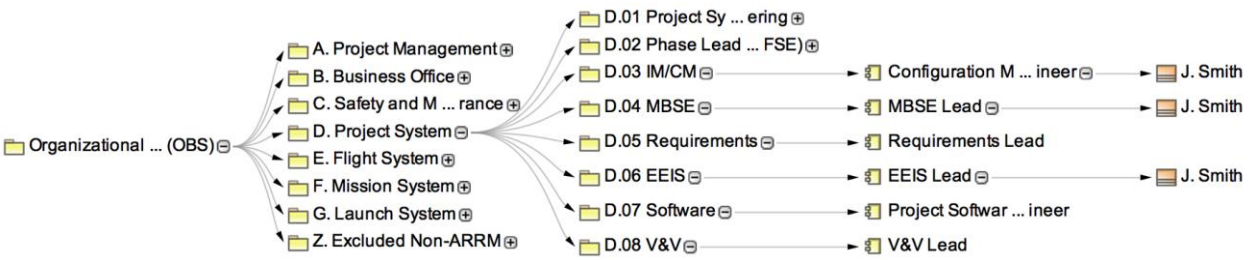
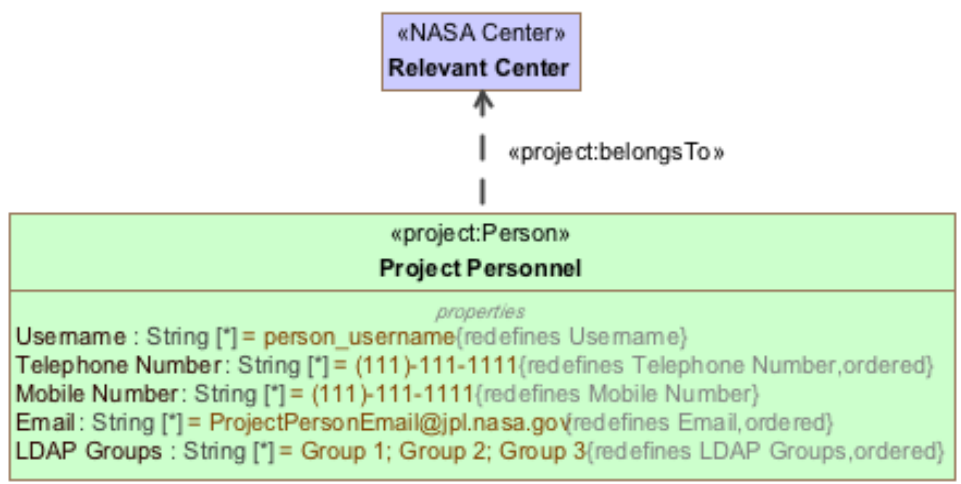
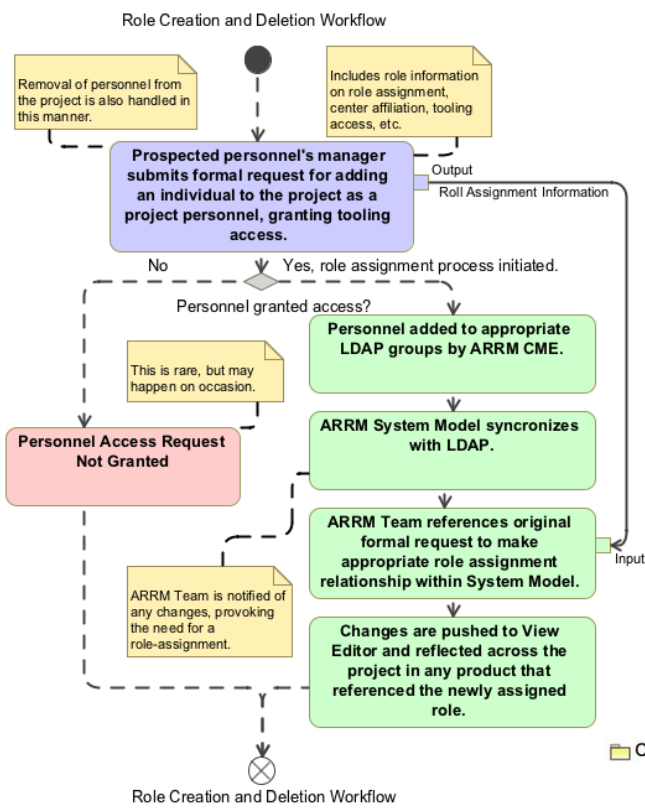
Document List

OBS	Name	JPL Document ID #	Released Document PDF Link	Document Preparer(s)	Document Owner(s)	Document Approver(s)	Draft Date	Preliminary Date	Baseline Date	Work Status	Revision	Cover Date	Release Date
D. Project Systems Engineering	ARRM Flight-Ground Interface Control Document	JPL D- [redacted]	Click Here for Official Document in Alfresco	Oleg Sindly	End-to-End Information Systems Engineer	Project Systems Engineer [redacted] Flight System Systems Engineer [redacted] Mission System System Engineer	KDP-B - 2016-07-15	KDP-B - 2016-07-15	System Design Review (SDR) - 2017-12-01	Prelim	Prelim	May 12, 2016	May 16, 2016



Personnel Metadata Definition

- Standardized process for definition of personnel, center affiliation & roles assignments
- Organizational Breakdown Structure (OBS)
- Tool & automation of personnel metadata via Lightweight Directory Access Protocol (LDAP)



Benefits Observed



- centralized project document database with up-to-date linkages to project personnel, schedule, and technical content
- modeled document linkages & usage propagate in real-time → create linkages between documents and other modeled elements, including requirements, personnel & project schedule elements
- project-wide content reusability & synchronization;
e.g., reuse of a single mission description across many documents
- versatility of presentation formats, while referencing the single-source-of-truth content
e.g., same requirement(s) can be presented in a table, diagram, or paragraph
- project-wide nomenclature definition → common repository of acronyms, abbreviations, units & glossary terms

Conclusions & Future Work



- MBSE can be expanded to manage programmatics of Systems Engineering activities of a project
 - MBSE can augment existing SE processes to deliver enhanced products over project life cycle
 - ARRM provided as an example of such an application effort for deliverables management, with modeling support for document generation and management with associated metadata for the project's documents, schedule & milestones and personnel
- Ongoing improvement efforts:
 - Automation of nomenclature term extraction
 - Receivables/Deliverables schedule
 - Autonomous cross-referencing
 - *etc.*

Acknowledgements



- Task managed out of NASA JPL, a division of Caltech
- ARRM is directed through Asteroid Robotic Mission (ARM) program with funding from Science Mission Directorate (STMD), Space Technology Mission Directorate (STMD) & Human Exploration and Operations Mission Directorate (HEOMD)
- ARM is part of “Asteroid Initiative” with funding from NASA’s Office of Chief Technologist
- ARRM is led by JPL in collaboration with NASA’s GRC, GSFC, LaRC, KSC, JSC and industry partners
- Work described leverages MBSE infrastructure & processes developed at JPL thru Integrated Model-Centric Engineering (IMCE), Systems & Software Computer Aided Engineering (SSCAE), Europa mission & institutional processes modernization efforts
- Members of the ARRM multi-center MBSE team:
 - Benjamin Cichy of GSFC
 - Kathryn Trase, Vicki Crable, and Edith Parrott of GRC
 - Charles Budney, Carl Steiner, Larissa Kupferschmidt, Chrisma Derewa, Farah Alibay, Matthew Rozek, Robert Castillo, and Sanda Mandutianu of JPL