Historical Review of Ares Technology Investment Process Flow

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Agenda

- Technology Program Leveraging
- NASA Technology Programs Overview
- MSFC Identified Ares Technology Needs
- Ares Technology Needs Process Definition
- Ares Candidate Technology Needs

Ares I & V Technology Program Leveraging

- **Ares Program Office (APO) requested an investment strategy to leverage a variety of technology programs to provide emerging capabilities in support of Program goals**
  - Operability
    - Manufacturing
    - Processing
    - Operations
  - Vehicle Performance Improvements
  - Vehicle Risk Mitigation
  - Ares 5 Advanced Development Needs

- **Technology programs available to leverage in 2007**
  - Constellation University Institutes Program (CUIP)
  - National Space Science and Technology Center (NSSTC) Collaborations
  - Small Business Innovation Research (SBIR)
  - Small Business Technology Transfer (STTR)
  - Innovative Partnership Program (IPP)
  - Exploration Technology Development Program (ETDP)
  - Rocket Propulsion Test Management Board (RPTMB)

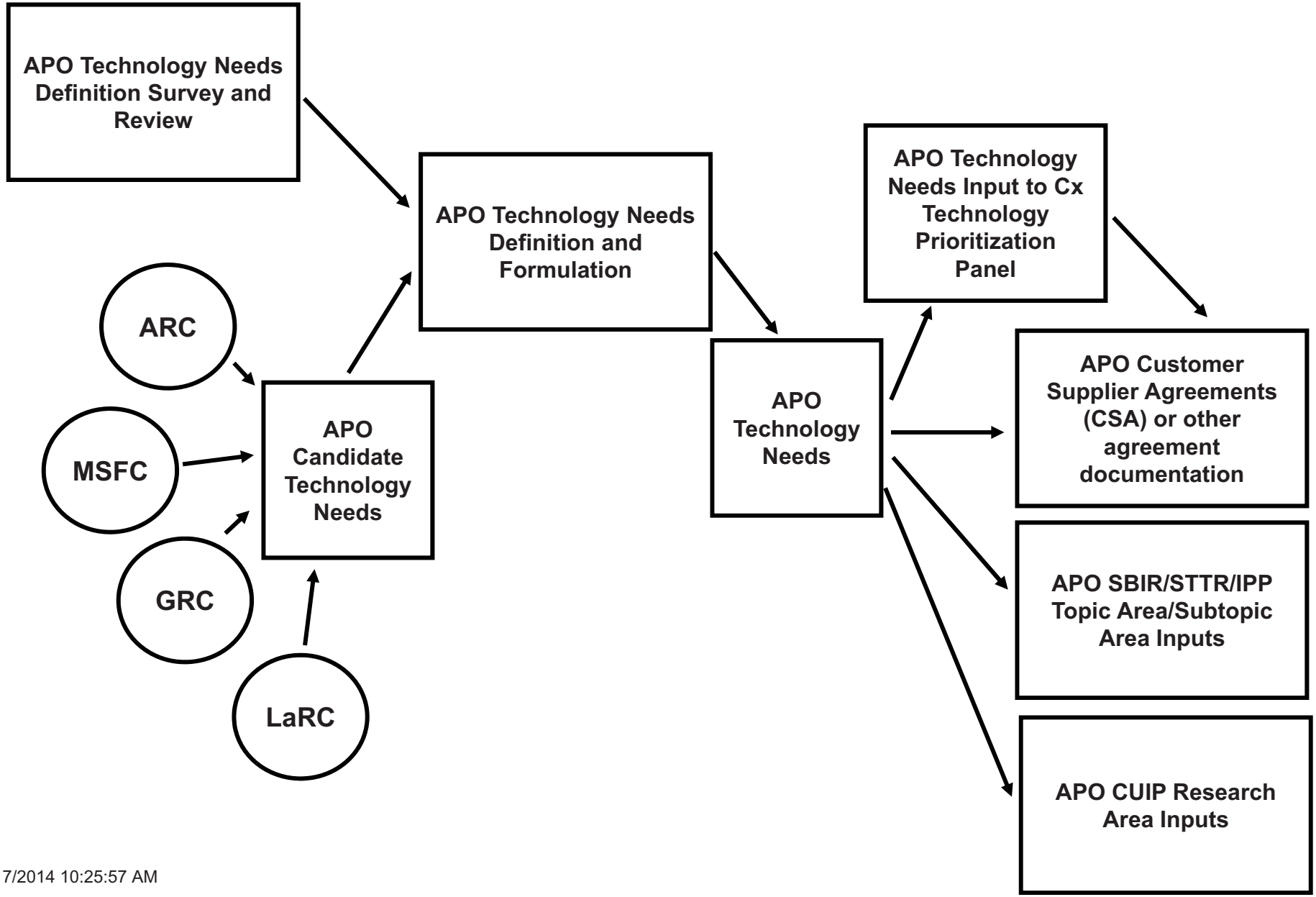
Ares Technology Needs Definition Process

Technology Portfolio Philosophy Demonstrated during Ares

- **Multiple Organizations Contribute to Technology Development**
  - Universities
  - Small Business
  - Medium/Large Business (Primes)

- **Each Organizational Class fits differing Technology Development Needs Differently**
  - Universities (Basic Research)
    - Basic Research – TRL 1-3
      - Low cost tasks
      - Higher risk areas
      - Path finding new and novel approaches
    - Technology Demonstration – TRL 4-6
      - Low to moderate cost tasks
      - Proof of Concept
  - Small Business (Application Development)
    - Basic Research – TRL 1-3
      - Low cost tasks
      - Application driven
    - Technology Demonstration- TRL 4-6
      - Moderate cost tasks
      - Application driven
  - Medium/Large Business (Product Demonstration)
    - Technology Demonstration – TRL 4-6
      - Moderate to high cost tasks
      - Product driven
    - Technology Maturation – TRL 7-9
      - Moderate to high cost tasks
      - Proof of Operational viability in Targeted Application

Technology Needs Definition



Ares Candidate Technology Needs Identification Process

- **Survey conducted of engineering and research organizations at ARC, GRC, LaRC, MSFC**
- **Input developed identifying proposed Technology**
  - Brief description
  - Clear need statement
  - CxP Milestone supported
- **MSFC inputs collected in July 2007 to path find collection process**
- **Research Centers and Exploration Technology Development Program (ETDP) Office briefed on process – August 2007**
- **Research Centers provided input – September 2007**
- **Inputs consolidated into a single list**

Ares Capabilities Value Stream

- **Abbreviated process with 2 objectives**
  1. Identify development needs not met with current capabilities
  2. Formulate capability/technology development to meet defined capabilities

- **Two phases to the process**

- **Phase 1: Identify development needs not met with current capabilities**
  - Input from system designers, chief engineers, lead system engineers, etc.
  - Simple survey questions to identify needs
    - **From your point of view describe the key technical challenges in designing to meet your requirements. If we could overcome the challenges what capability/technology would allow us to significantly improve margins or push the requirement further?**
      - **Examples**
        - **Mass of subsystem**
        - **Reliability of subsystem**
        - **Number of maintenance items**
        - **Thermal capability**
        - **Specific material properties**
    - **Can you identify any worthwhile technologies that could address your technical challenges?**
  - Input evaluated and prioritized by a Technology Review Panel

Ares V Technology Needs Prioritization
Phase I VSM Event November 1, 2007

- **Multi-voting Technique**
  - Purpose
    - To assess which ideas have the most group energy behind them.
  - What does it do?
    - Prioritizes the list of technology needs through a weighting process.

- **Method: Dot-Voting- Multiple vote per item**

- **Each Review Panel member has votes equal to 1.33*technology needs**
- **Each team member votes for each technology. The more votes given, the higher the priority given by the voter.**
- **Tabulate the results. The highest priority is determined by the highest number of total votes from the panel.**
- **Discuss, adjust voting based on subjective considerations, and reach consensus on priority.**
- **In the event that several items have equal high priority, a second round of voting using a single vote process was used to refine the list**
  - Each panel member gets number of votes equal to 0.33*high technology needs. Each panel member can give one vote per technology need.
  - Tabulate the results. The highest priority is determined by the highest number of total votes from the panel.
  - Technology needs with no votes in this round get ranked at the bottom of the high priority list.

APO Technology Priority Groups

- Composites (15/232)
- Cryogenic Fluid Management (6/88)
- Solids (4/57)
- Automation (6/38)
- Liquid Propulsion (5/28)
- Control/Separation (6/26)

Ares Capabilities Value Stream

♦ Phase 2: Formulate Technology Plan

- Aligned capability needs with technology providers
- Defined specific approaches/products which satisfy the design needs
- Reviewed candidate technologies
  - Initial filtering to match capability needs with candidate technologies
  - Obtain feedback from system designers on candidate technologies
    - If matured, would any of the proposed technologies significantly improve the ability for you to meet or exceed your requirements or decrease the risk in doing so?
      - Identify those as high, medium, or low to no improvement
      - If you have time provide a few words as to why
- Design Teams worked with Technology Providers to formulate technology development
  - NASA Research Centers
  - MSFC Engineering Directorate
  - Industry Partners
  - Universities
- Results documented in the Customer Supplier Agreement (CSA) or other documentation of agreed to technology products and approach

CxP Technology Prioritization Panel (TPP) Input

- **Phase 1 Ares Identified Technology Needs mapped to Candidate Technology inputs from MSFC Engineering Directorate, ARC, GRC, LaRC**
  - Matched needs with candidate technologies
  - Removed candidates without any pull
    - Review for potential referral to design teams for consideration
- **Request technology proposers to develop final package for Ares Project Office input to CxP TPP**
  - Package to be reviewed by customer design teams to ensure proper focus
- **Input Packages provided to CxP TPP – 7 Dec 2007**
- **Appropriate needs were input to SBIR/STTR/IPP for 2008 Topic/Subtopic development**
- **Appropriate needs were input to CUIP for formulation of University projects**
- **Needs list provided to Von Braun Center for Science and Innovation (VCSI) and other industry partners for external development consideration**
- **CxP TPP Ranking input on 15 Dec 2007**
- **Phase 2: Formulated approved projects with ETDP – 2nd Quarter FY2008**
  - Produce Customer Supplier Agreements (CSA)

Constellation Technology Prioritization Panel (TPP) Prioritization Methodology

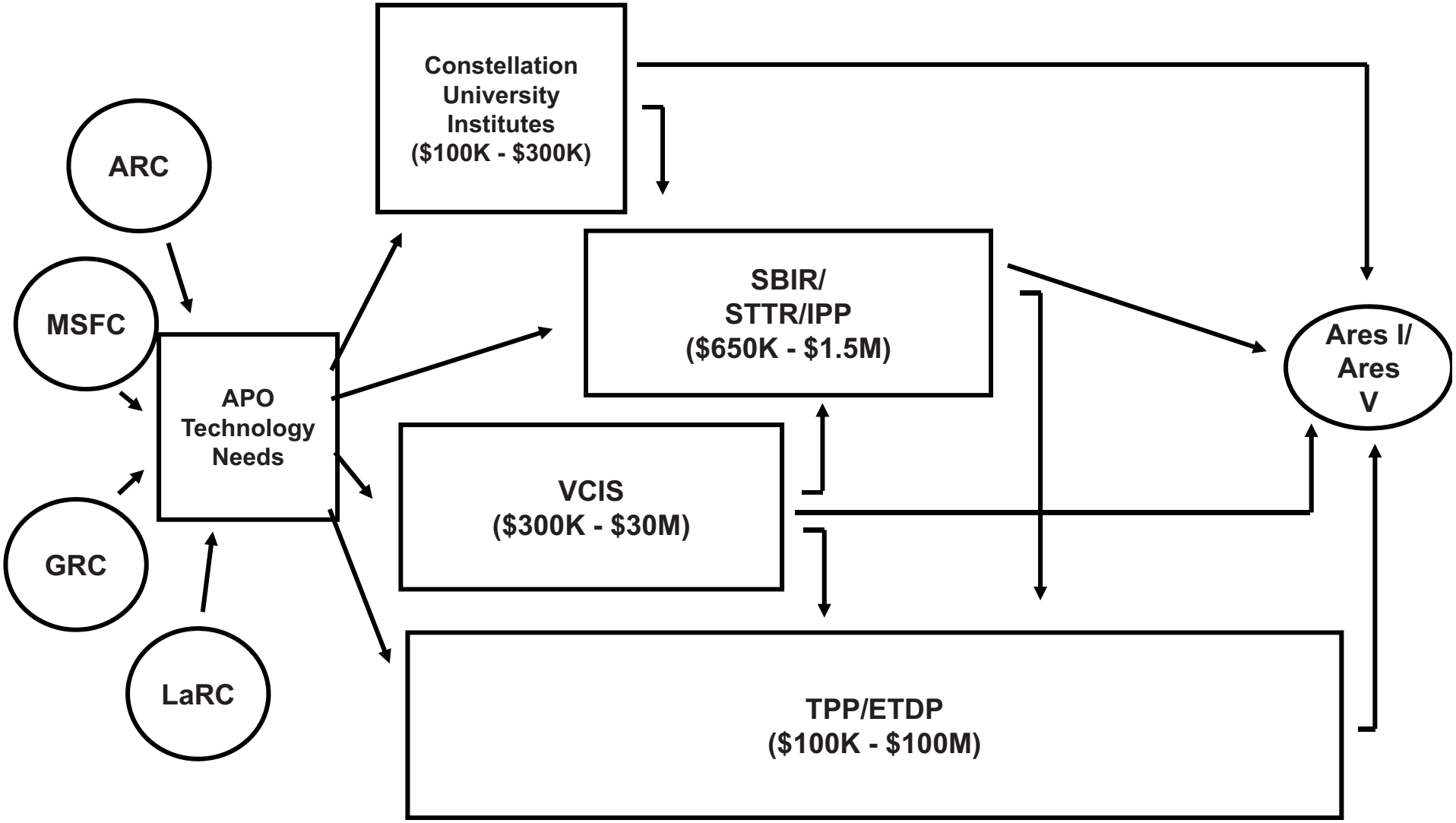
- Prior to the TPP, members were responsible to:
  - Review justification packages
  - Verify appropriate criticality (critical, HD, desirable)
  - Rank needs independently
- TPP as a panel was responsible to:
  1. Ask ROs questions
  2. Blind Vote
  3. TPP members review results of the "voting"
  4. Discuss results and adjust if required
  5. Reach consensus or agree to disagree

Count of ID	Initial Capability				Lunar Surface				Lunar Transport				Mars			
Submitting Project/SIG	Critical	Highly Desirable	Desirable	IC TOTAL	Critical	Highly Desirable	Desirable	LS TOTAL	Critical	Highly Desirable	Desirable	LT TOTAL	Critical	Highly Desirable	Mars TOTAL	Grand Total
Project - Ares	5			5					10			10				15
Project - EVA Systems	1			1					7			7				8
Project - Ground Operations	11			11												11
Project - Lunar Lander									10	4	6	20				20
Project - Lunar Surface Systems		1		1	36	50	18	104	2	3	1	6				111
Project - Mission Operations		7		7		7		7		7		7				21
Project - Orion	7	6		13	1			1	7	7		14		1	1	29
SIG - Environments & Constraints					1	6		7		3		3				10
SIG - Ground & Mission Ops						2		2	1			1				3
SIG - Integrated Loads, Struct & Mech	6	5	1	12	7	14	11	32	1	1		2				46
SIG - Integrated Power Loads		1		1	3	1		4	1	2		3				8
SIG - Supportability, Oper, Afford						4		4								4
SIG - SW & Avionics Integration Office	2	3		5	4	2	1	7	4	12		16	3		3	31
SIG - Thermal & ECLSS	1	4		5	13	15	2	30	4	12	2	18				53
SIG- Flight Performance	1			1					3			3				4
Grand Total	34	27	1	62	65	101	32	198	50	51	9	110	3	1	4	374

TPP Inputs - Linked to Ares Projects Office Risks

Risk ID	Risk Title	Risk Score	Technology Title
2736	Shell Buckling Factors	L=4 C=4	Shell Buckling
1144	Welding Development on Low TRL Processes	L=2 C=4	Friction Stir Welding of Spun Formed Dome
1146	Lack of a Manufacturing Technique for Close Out of Through-thickness Holes Resulting from Friction Stir Welded Circumferential Welds	L=2 C=5	Friction Stir Welding of Spun Formed Dome
2728	Solid Rocket Motor Fault Detection Technology	L=3 C=5	Solid Rocket Motor Health Management./Ares 1-X Gound Experiment
2725	Large Composite Manufacturing Technology	L=4 C=5	Large Composite Manufacturing
2647	First Stage TVC Risk Mitigation	L=4 C=4	TVC architecture development to minimize operations (EHA Ares I upgrade)
2738	HTPB Propellant Characterization	L=4 C=4	HTPB Propellant
2727	Long-term Cryogenic Storage	L=4 C=5	Long-term Cryogenic Storage
2730	Composite damage tolerance/detection	L=4 C=5	Composite damage tolerance/detection
2729	EDS state determination/abort	L=4 C=5	EDS state determination/abort
2731	Composite joining technology	L=4 C=5	Composite joining technology
2732	EDS Tank On-orbit Fluid Measurement	L=4 C=5	Liquid Level Measurement
2733	Large Tank Multi-layer Insulation Techniques	L=4 C=5	Multi-layer Insulation
2734	On-orbit Leak Detection	L=4 C=5	Leak detection
2735	Nozzle sensitivity to pocketing/ ply lifting using HTPB with higher heat flux	L=4 C=5	Nozzle sensitivity to pocketing/ ply lifting using HTPB with higher heat flux
2737	Pneumatic actuator stage seperation systems	L=4 C=5	Pneumatic actuator system- primarily guided actuator (related to gas struts)

Technology Maturation Path for Ares Project Office (APO)



NASA Technology Development Programs Overview

Constellation University Institutes Program (CUIP)

- **Constellation University Institutes Project (CUIP)**
  - Project managed by GRC/Claudia Meyer and Jeff Rybak
  - Consists 6 Virtual Institutes with NASA Experts as Technical Leads
    - Thrust Chamber Assembly (MSFC//Kevin Tucker)
    - Propellant Storage and Delivery (MSFC/Dan Dorney)
    - Reentry Aerothermodynamics (ARC/Mike Wright)
    - Structures and Materials for Extreme Environments (LaRC/Kevin Rivers)
    - Solids (MSFC/Robert Garcia)
    - Systems Engineering and Integration (GRC/Claudia Meyer)
  - A Consortium of Universities funded through a Cooperative Agreement
    - Funding: ($4M/year) by Constellation; ESMD contributes $3.5M for FY08 only
      - Reformulating to include Ares technology needs from CUIP into other funded areas if funding not provided by Constellation
    - Allocation of funds depends on research requests against the tasks established in each Virtual Institute
    - Funding is nominally in the $150K/task range
    - New Cooperative Agreement
      - University of Maryland is lead university
      - 1 October 2007 start date
      - Maximum duration: 5 years

Constellation University Institutes Program (CUIP)

- **Thrust Chamber Assembly Virtual Institute**
  - MSFC/Kevin Tucker
  - Research Areas
    - CFD Code Development and Verification
    - Validation at the Injector Unit Physics Problem Level
    - Validation at the Injector Model Problem Level
    - Thrust Chamber Assembly Performance
    - Thermal Environments
    - Combustion Stability

- **Propellant Storage and Delivery Virtual Institute**
  - MSFC/Dan Dorney
  - Research Areas
    - Computational and Experimental Investigation of Cavitation
    - Mesh Generation
    - Turbomachinery design optimization
    - Multi-phase CFD Code Development and Verification

- **Reentry Aerothermodynamics Virtual Institute**
  - ARC/Mike Wright
  - Research Areas
    - Aerothermodynamics of Earth re-entry
    - TPS modeling and flight performance
    - Mid-term architecture improvements for Block-III

Constellation University Institutes Program (CUIP)

- **Structures and Materials for Extreme Environments Virtual Institute**
  - LaRC/Kevin Rivers
  - Research Areas
    - Modeling of durability of metals and composites
    - Joining of dissimilar materials
    - Integrated structural health monitoring
    - MMOD resistant back-shell TPS
    - Modeling of oxidation in ceramic composites

- **Solids Virtual Institute**
  - MSFC//Robert Garcia
  - Research Areas
    - Erosive Propellant Burning Simulation in Solid Rocket Motors
    - Validation Data for Erosive Burning Simulations
    - Solid Propellant Characterization Techniques
    - Solid Rocket Motor Nozzle Material Performance

- **Systems Engineering and Integration Virtual Institute**
  - GRC/Claudia Meyer (acting)
  - Research Areas
    - Detailed Lunar Exploration Campaign Logistics Analysis
    - Lunar Environment Modeling and Data Analysis
    - Liftoff Acoustics Characterization
    - Trajectory Planning and Tracking

SBIR/STTR/IPP

- **Small Business Innovation Research (SBIR)**
  - Development of a High TRL technology by a small business with or without subcontractors
  - Phase 1: $100K, 6 months
  - Phase 2: $650K, 2 years
  - Phase 3: Project funded, no funding or time limits mandated
    - APO is committed to providing Phase 3 funding for those activities which show benefit to Ares developments

- **Small Business Technology Transfer and Research (STTR)**
  - Joint Development of a Technology by a Small Business and Non-Profit such as an FFRDC, University (JPL is not eligible beginning this year)
  - Phase I: $100K/contract, 1 year
  - Phase II: $700K/contract, 2 years

- **Innovative Partnership Program (IPP)**
  - A joint development program consisting of NASA and Industry partners focusing on high TRL capabilities
  - $9.2M available in FY08 across the agency
    - MSFC can submit 8 proposals center wide
    - Typically $750K - $1.5M, 1 year
  - Partnership Funding Split
    - 1/3 IPP
    - 1/3 NASA Program or Center
      - Can be in kind (e.g., FTE support)
    - 1/3 Industry Partner
    - FY07: $974K HQ/MSFC IPP Funds; $640K MSFC Funds; $3.7M Partner Funds

SBIR/STTR/IPP Topics in Support of Ares I & V Development

- **Manufacturing**
  - Digital Design to Manufacturing
  - Rapid Prototyping
  - Human Motion Tracking Analysis Tools
- **Thermal Protection System (TPS)**
  - High Temp Ablative for Boosters
  - Cryogenic Tank Insulation (Lightweight)
  - MMOD Protective MLI for Cryo Tanks
- **Metallic Structure**
  - Lightweight Materials and Structures
  - Friction Stir Welding
- **Composite Structures**
  - Composite Failure Detection and Identification
  - Composite Cryo Tanks
  - Dry Composite Structure
  - Composite SRM
- **Solid Propulsion**
  - Pyrotechnic Design Tools
  - SRM/Hybrid Motor Analysis Tools
- **Valves and Actuators for Liquid Engines**
  - Advanced Component Design
    - Advanced TVC
    - Fault Tolerant Ball Screws
    - Electronic Control Relief Valves
    - Redundant Piezo-Electric Actuators
  - Analysis and Design Tools
    - Valve Sizing and Mass Estimation Tools

SBIR/STTR/IPP Topics in Support of Ares I & V Development

- **Cryogenic Fluid Management**
  - Leak Detection
  - Thermal Protection
  - Pressure Control
  - Mass Gauging
- **Liquid Engine Propulsion**
  - Simulation and Modeling Techniques
    - Multiphase Flow
    - Transient State Models
    - Turbo Machinery Modeling
  - Cryogenic Seals
- **GN&C**
  - Adaptive/Augmented GN&C
- **Integrated System Health Management (ISHM)**
  - Vehicle State Determination
    - Algorithm and Sensor Approaches to Measure Vehicle States and Conditions
- **Separation Systems**
  - Gas Struts
  - Other Innovative Techniques

National Space Science and Technology Center (NSSTC)

- **Partnership between NASA and Academia**
  - Marshall Space Flight Center
  - University of Alabama in Huntsville (UAH)
    - NSSTC Executive Director
  - Alabama A&M University
  - Auburn University
  - Tuskegee University
  - University of Alabama
  - University of Alabama in Birmingham (UAB)
  - University of South Alabama
  - Cooperative Agreement extended through 2010
- **Encompasses several research areas**
  - Global Hydrology and Climate Center (GHCC)
  - Propulsion Research Center
  - Material Science Research Center
  - Biotechnology Research Center
  - Space Science
  - Information Technology
  - Advanced Optics
- **Funding through**
  - Competitive Procurements
  - Direct NASA Program Support
  - Congressional Initiatives

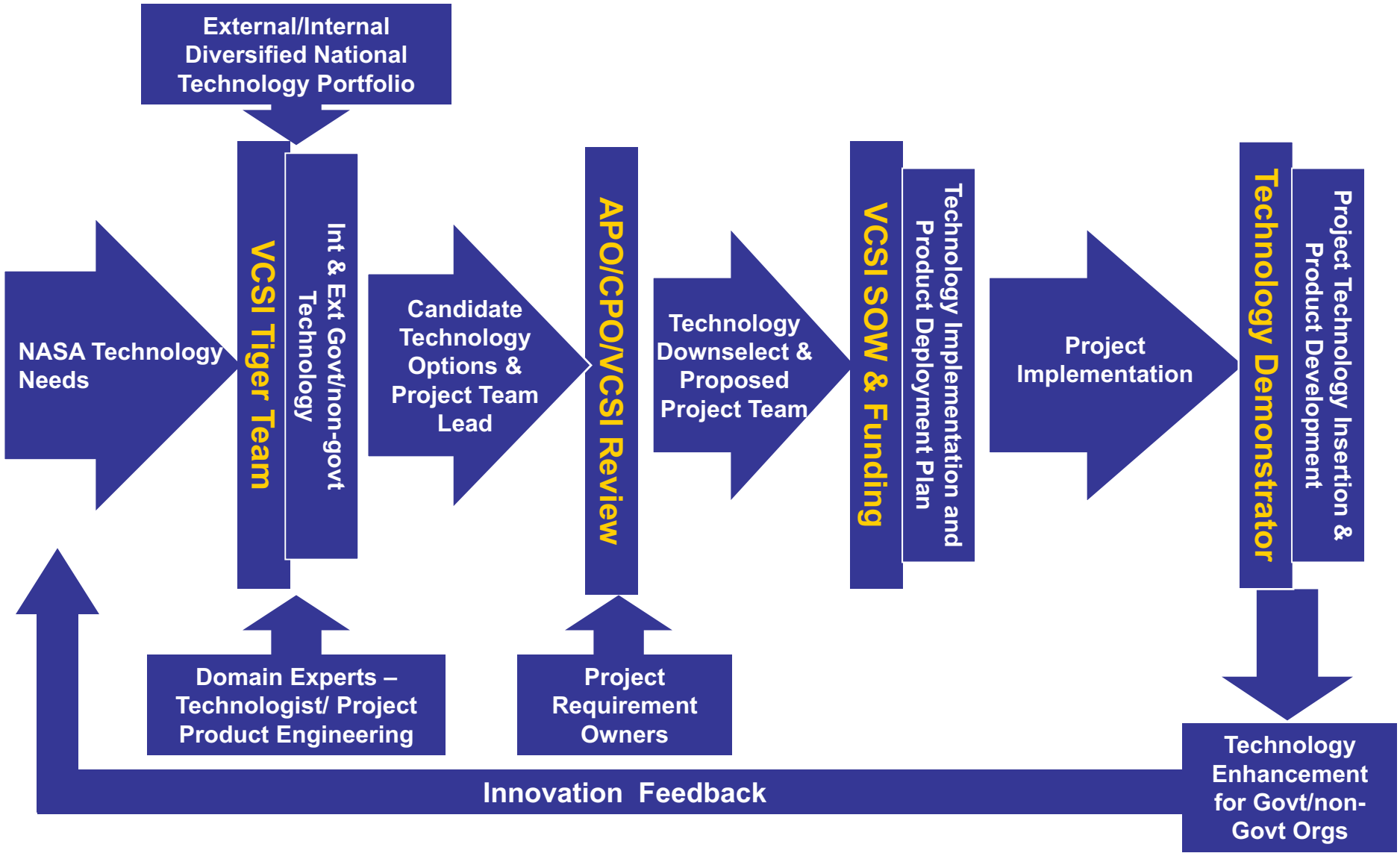
Von Braun Center for Science and Innovation

- Not-for-profit organization (501(c) 3) incorporated in August 2006
- Integrates government, industry, and academic R&T assets to provide customers with science applications and engineering solutions through collaborative programs
- Member-based organization comprised of corporate, government, university, and other strategic organizations
- Governed by industry and university affiliated Board of Directors – also includes key government liaisons (MSFC, SMDC, AMRDEC,TVA, MDA)

VCSI's objectives are to:

- Develop and implement requirements-driven technology programs
- Identify and link emerging technologies from the national R&T community to address customer requirements
- Promote/implement innovative management approaches to technical solutions

VCSI Requirements-Driven Model



Other Technology Programs

- **Rocket Propulsion Test Management Board (RPTMB)**
  - Managed out of Stennis Space Center (SSC)
  - Focuses on technology to improve propulsion testing quality, reliability, and consistency
  - Funds approximately 8 projects/year
  - Funding distributed among several centers
- **NASA NonDestructive Evaluation (NDE) Working Group (NNWG)**
  - Funds NDE technology development
- **Space Communications and Navigation (SCAN)**
  - SCAN provides funding for communication technology

Exploration Technology Development Program (ETDP)

- **Exploration System Mission Directorate (ESMD) technology development program ($316M in FY08)**
- **A peer program to Constellation**
  - Constellation and the Lunar Architecture Team (LAT) are the only customers driving ETDP projects
  - There are some legacy International Space Station (ISS) experiment tasks in the ETDP budget
- **Constellation went through an initial prioritization task with Constellation and LAT in Spring 2007**
  - Inputs were collected quickly and Constellation does not have a complete set of technology needs identified
    - Expect a new prioritization effort this Fall
  - APO input two tasks
    - RS68 turbopump development for Ares V
      - Cancelled due to instabilities with Air Force agreements
    - Solid Rocket Motor (SRM) Health Management
      - Funded through 2009
  - APO had two other existing projects
    - Friction Stir Welding
      - Funded jointly by ETDP and APO
    - 600 lb Thruster
      - Cancelled and funded in-house by APO as a required Ares component

ETDP – Crew Systems (CEV, LSAM, MTV)

- **ETDP is organized into several elements with projects under each one**
  - Structures, Materials, and Mechanisms
    - *Advanced Radiation Shielding
  - Protection Systems
    - Ablative Thermal Protection System for CEV
    - *Future Aerocapture Technologies
  - Non-Toxic Propulsion
    - Propulsion and Cryogenic Advanced Development (PCAD)
    - *Cryogenic Fluid Management
    - *Advanced Propulsion Technologies
  - Energy Storage and Power Systems
    - Energy Storage
  - Environmental Control and Life Support
    - Exploration Life Support
    - Advanced Environmental Monitoring and Control
    - Fire Prevention, Detection, & Suppression
    - *Advanced Waste Techniques
    - *Planetary Protection Technologies
  - Crew Support and Accommodation
    - EVA
    - *Advanced EVA
  - Advanced Fission Based Power Systems
  - Avionics and Software
    - Radiation Hardened Electronics for Space Environments
    - Integrated System Health Management
    - Automation for Operations
    - Reliable Software
    - Auto Precision Landing, Guidance, Navigation
    - Autonomous Rendezvous and Docking (AR&D) Sensors
    - Mini-RF/LRO
    - *High Bandwidth Optical Communications
    - Non Line of Sight High Frequency (HF) Communications
    - *Advanced Entry, Descent, and Landing (EDL) for Large Payloads

MSFC Supported Task in 2007

ETDP – Surface Systems

- Avionics and Software
  - Radiation Hardened Electronics for Space Environments
  - Automation for Operations
  - Reliable Software
  - Non Line of Sight High Frequency (HF) Communications
  - *Surface System Sensors
- In-Situ Resource Utilization
  - ISRU
  - *Mars Propellant ISRU
- Protection Systems
  - Dust Mitigation
- Thermal Control for Surface Systems
- Robotics, Operations & Supportability
  - Supportability
  - Human Robotic Systems

MSFC Supported Task in 2007

ETDP – Launch Vehicles

- Structures, Materials, and Mechanisms
  - Structures, Materials, and Mechanisms
- Energy Storage and Power Systems
  - Energy Storage
- Avionics and Software
  - Radiation Hardened Electronics for Space Environments
  - Integrated System Health Management

MSFC Supported Task in 2007

ETDP – Overhead

- Program Support
  - Program Support
  - System Design and Analysis Tool Development
  - Systems Analysis and Technology Assessment
- ISS Research Development and Operations
  - Exploration Research
  - Non-Exploration Research
- ETDP Special Projects
  - NEOO
  - Earmarks
  - ETDPO Operations
  - ETDPO Integration
  - NASA Institute for Advanced Concepts (NIAC)
  - ETDP New Start Projects
  - Technology Validations

MSFC Supported Task in 2007

Summary

- **Ares Program Office developed a technology development model that incorporated research organizations with appropriate research tasks**
- **APO was successful in defining, defending (in tough budget periods) and progressing all vital technology needs**
  - Strong dependent on the coupling of design team needs to appropriate technology providers (needs driven technology development)
- **APO model is valid today and provides a road map to involve all levels of research and development organizations to productively contribute to a programs technology needs**
- **APO model is readily adapted to new research and development structures as demonstrated in the APO model adaption to various late changes in technology program structures**
  - TPP emergence to drive ETDP needs
- **There are several new trends…**

Current and Future Trends

- **Current and Future focus is on collaboration of Universities through a centralized contract**
  - National Institutes
    - National Institute for Rocket Propulsion Systems (NIRPS)
    - Digital Manufacturing and Design Institute (DMDI)
    - National Additive Manufacturing Innovation Institute (NAMI)
    - Lightweight & Modern Metals Manufacturing Innovation Institutes
    - Next Generation Power Electronics Manufacturing Innovation Institute
  - Research Consortiums
    - University Institutes Program (UIP) model
    - DoD System Engineering Research Center (SERC)
    - NASA System Engineering Research Consortium
    - NSF e-design Center
- **National Initiatives**
  - Cuts across and coordinates Multiple Funding Organization Opportunities
  - National Nanotechnology Initiative
  - National Robotics Initiative