♦ CUIP Objectives, Philosophy, and Organization

♦ The CUIP Virtual Institutes

♦ Summary
Adapted from original 2001 URETI solicitation…

- **Perform** research and development that addresses critical Constellation needs.
- **Enhance** and broaden the ability of the nation’s universities to meet the needs of NASA’s programs.
- **Expand** the nation’s talent base for NASA mission-related research and development and technology maturation.
- **Strengthen** NASA’s ties to academia through long-term, directed, and sustained investment.

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The CUIP shall continue to build, through Cooperative Agreements, capability of US universities to address technical challenges in ESMD’s programs and projects. The CUIP capability, through its network of 18 universities, shall be in the following areas: Thrust Chamber Assemblies, Propellant Storage and Delivery, Structures and Materials for Extreme Environments, Re-entry Aerothermodynamics, and Systems Engineering and Integration. The CUIP is managed out of the Glenn Research Center, with technical expert support coming from Ames Research Center, Glenn Research Center, Johnson Space Center, Kennedy Space Center, Langley Research Center, and Marshall Space Flight Center. – Based on Program Operating Plan, CUIP Narrative

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**CUIP Cumulative (since 2003) Stats**

<table>
<thead>
<tr>
<th>Category</th>
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<tr>
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The CUIP Philosophical Pillars

**Integration**
- Tight
- Business and Technical

**Engaged Guidance**
- NASA Points-of-Contact
  - Big-Picture perspective
  - Consumers of deliverables
  - Orient each task

**Collaboration**
- Universities and NASA
- Universities and Industry
- Universities and Universities
- “Whole is > sum of parts”

**Technology Pull**
- Customer: Constellation

Close NASA involvement in task scope definition, evaluation, and interaction has been and will be key to the continued effectiveness of CUIP.
Procedure for bringing new tasks into the CUIP technical portfolio (pending funds)

**Discovery Process**
- New Task Identification
- Official Submit from CUIP
- UMd. Provides Solicitation

**Technology Pull**
- NASA POC / Stakeholder writes task topic and submits to CUIP Management Team.
- CUIP Management Team helps prepare / finalize the new task write-up then submits to the University of Maryland One CUIP Management Team to initiate announcement to university research community.
- University of Maryland One CUIP Management Team provides official communication to the university subcontractors about the new task topic. Other universities outside of the CUIP can be invited to propose, as well.
- Interested university researchers submit proposals to the CUIP Management Team.
- CUIP Management Team works with the VI Team(s) and other stakeholders to decide on selection.
- CUIP Management Team and the GRC Contracting Officer must modify the cooperative agreement in the event that a new task(s) is added. For this reason, “one-shot” loading of new tasks is preferred as opposed to a scattered, one-at-a-time format.

**Decision Process**
- Cooperative Agreement Modification
- CUIP Management Team Receives Proposals
The CUIP Network of Task POCs

CUIP has Task POCs in many Constellation Projects/Offices
**NASA Constellation University Institutes Project**

Some History of CUIP

- Review of Each Task
- Input from Industry/DoD/NASA

**Mid-Year Technical Review**

53 Task Presentations
April 4-7, 2005
Huntsville

**Annual Update to Task Plans**
September 2, 2005

**Re-Entry Aerothermodynamics Virtual Institute Meeting**
January 18, 2006
Houston

**SMEE Virtual Institute Meeting**
June 6, 2006
Houston

Dec 2004
Jan 2005
Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan 2006

- Management of CUIP
- Review Strategies
- Enhancing the Foundation

**TCA Virtual Institute Kick-Off Meeting**

September 16, 2005
Syracuse

**TCA Task Reviews**

January 4, 2006
Michigan

January 5, 2006
Maryland

**TCA Task Reviews**

March 8-9, 2006
Florida
Georgia Tech
Michigan
Mississippi State

**TCA Task Reviews**

Fall 2005
Auburn
Penn State
Purdue
Tuskegee
UAH

**Strategy Summit**

January 25-26, 2005
College Park
24 Universities
* U. of Maryland is management lead

6 Virtual Institutes (VI)
* Each VI is led by NASA

50 Technical Tasks
* Addressing technical challenges to Constellation
* 1 NASA point-of-contact per task; stakeholders
The Virtual Institutes at a Glance
APPROACH AND FOCUS
Develop/improve, verify and validate high fidelity fluid dynamic simulation capability to be used for design, analysis, test support and anomaly resolution

Focused on critical aspects of Constellation Systems combustion devices design:

- Performance (P)
- Thermal Environments (TE)
- Combustion Instability (CI)

APPLICATION TO CONSTELLATION
Maturing tools and data from this effort have been and are being used to support Cx design efforts in the following areas:

- First stage propulsion
- Upper stage engine
- Mobile launch platform
- Lunar descent/ascent propulsion
- Roll control thrusters
- Launch abort system
- Ullage settling motors

ACCOMPLISHMENTS
- Provided CUIP-developed CFD combustion code (with continuing support) to 10+ organizations supporting Cx
- Injector simulation validation (P, TE, CI)
  - Completed steady & unsteady single element validation (P, TE); results successfully applied to J-2X 40k testing @ MSFC
  - Test-fired J-2X-like multi-element injector (P, TE)
  - Used CUIP-generated data to establish capability of range of CI tools; working on CFD CI roadmap
- Defined experiment to validate CFD models for J-2X nozzle extension film cooling (TE)
- Developed efficient injector CI screening test capability
**APPROACH AND FOCUS**

- Developing computational tools for improved design and analysis of Main Propulsion System (MPS) and turbomachinery components.
- Address issues of improving model fidelity for cryogenic fluids and the phenomena that occur as the propellant moves from the tank into the engine.
  - Improve the analyses and processes used to design/analyze liquid fueled engines.

**APPLICATION TO CONSTELLATION**

Knowledge and tools will be used to improve the design and operation of first stage/upper stage RCS, Upper Stage MPS and J-2X, CLV/CEV propellant tanks, and the lander MPS/engine.

**Tasks**
- Computational Investigation of Cavitation
- Experimental Studies of Simulated Cryogenic Cavitation
- Multi-phase CFD Code Development and Verification
- Turbomachinery Design Optimization
- A Parametric and Automated Mesh Generation Template Tool

**ACCOMPLISHMENTS**

- Developed and validated an adaptive grid technique for resolving and tracking fluid/gas interfaces in CLV Upper Stage tank draining simulations
- Improved the fidelity of cryogenic cavitation/two-phase models, and applied the improved algorithms to CLV pump and tank geometries
- Demonstrated the Advanced Mesh Generation Template Tool, MiniCAD, on volute, manifold and tank geometries representative of those used on the Ares vehicle.
- Applied turbomachinery optimization techniques to the design of a vaned diffuser for a conceptual expander cycle engine
**APPROACH AND FOCUS**
Focus on near and mid-term technology development to reduce the risk of Earth re-entry as required for CEV Block-I and beyond:

- Hybrid Continuum-Particle Method for Nonequilibrium Hypersonic Reentry
- Modeling of High-Energy Nonequilibrium Flow Physics
- Uncertainty Analysis of Surface TPS Ablation Models
- Hypersonic Boundary Layer Transition on Capsules Due to Roughness and Blowing
- Basic Interactions Between Turbulence and Radiation in Hypersonic Turbulent Boundary Layers
- Wireless Sensors for Thermal Protection Systems
- Error Estimation in Heat Transfer Predictions Using Overset Grids for Aerothermodynamics
- Optimization of Blunt-Body Reentry Configurations
- Mars Exploration EDL System Architecture Assessment

**APPLICATION TO CONSTELLATION**
Tasks were chosen to target key technology development areas that will benefit major ESMD stakeholders, including CAP\(^1\), TPS-ADP\(^2\), LeX\(^3\) and MAT\(^4\)

- **Five tasks focused on aerothermodynamics of Earth ascent and re-entry (CAP, LeX)**
- **Two tasks focused on TPS modeling and flight performance (TPS-ADP, LeX)**
- **Two tasks focused on mid-term architecture improvements for Block-III (CAP, MAT)**

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\(^1\)CAP=CEV Aeroscience Project  \(^2\)TPS-ADP=Thermal Protection System Advanced Development Project  \(^3\)LeX=Lunar eXentry eXperiment  \(^4\)MAT=Mars Architecture Team
APPROACH AND FOCUS

Develop/improve, verify and validate high fidelity computational tools and advance the SOA in structural concepts

Focused on critical aspects of Constellation Systems structural subsystems:

- Performance (mass)
- Reliability (durable, MMOD resistant)
- Diagnosis (SHM)

APPLICATION TO CONSTELLATION

Tasks were chosen to target key technology development areas that will benefit major ESMD stakeholders, including Ares, CEV, TPS-ADP\(^1\), LeX\(^2\) and Lunar Lander

- Diagnosis and Prognosis of Space Structures for Integrated Systems Health Management
- Damage Tolerance of PMCs for CEV and CLV
- Computational Simulation of Damage Tolerance for Composite and Metallic Structures
- Integrated Thermal Protection Systems
- Physics and Chemistry Based Multi-Scale Modeling of Oxidation of High Temperature Ceramic-Matrix Composites
- Strength and Durability of Joints for Space Vehicle Structures at Elevated Temperatures

\(^1\)TPS-ADP=Thermal Protection System Advanced Development Project
\(^2\)LeX=Lunar rEentry eXperiment

ACCOMPLISHMENTS

- Advanced the SOA in damage tolerance determination for PMCs (comprehensive test suite and reduction in amount of testing required)
- Damage and Durability Simulator for metallic structures was completed, verified, and substantially validated
- Experimental validation of diagnosis of potential damage modes in (spacecraft interior) metallic structures using Guided Wave (GW) technology
- Completed sensitivity analysis of several standard tests for determining fracture toughness and strength of bonded joints: discovered previously un-modeled relationship between strength and toughness that is being incorporated into predictive capability
- Integrated TPS: analytical methods, required in optimization studies, predict stresses and buckling loads within 5% of finite element analysis results
APPROACH AND FOCUS

***CUIP addresses immediate, near term, and long-term needs in solid propulsion***

- Immediate need for young engineers in solid propulsion
- Improved tools to support motor development/qualification (analytical, experimental)
- Building capability at universities to mix and/or test their own formulations
  - Precursor to advanced propellant research

APPLICATION TO CONSTELLATION

- Constellation will have at least 6 different solid motors on CLV alone
  - 5 of the 6 are new designs that will be developed over next 3-4 years
- Task Portfolio
  - Solid Propellant Characterization Techniques
  - Validation Data for Erosive Burning Simulations
  - Erosive Propellant Burning Simulation in Solid Rocket Motors
  - Solid Rocket Motor Nozzle Material Performance

ACCOMPLISHMENTS

- Construction of propellant mixing station has been completed
- Ballistics code being used as an aid in preliminary design of the test motor
- Successful room temperature tests on Army’s Aviation and Missile Research Development and Engineering Center propellant formulation
The CUIP Management Support System

(a.k.a., The CUIP Web Site)

- NOT an external, PR-focused web site
- Centrally-coordinated repository of expert documentation, reports, and presentations
- Facilitates project communications
- Archive catalog of all CUIP activities
- Operations “anchor” for the CUIP
- Designed, Developed, Implemented, and Maintained by CUIP Management Team

Each of the 50 CUIP tasks has its own web page that contains downloadable task documentation.
CUIP impacts Constellation system **design**

- Evaluated J-2X Nozzle side loads for ground testing
- Predicted CEV Launch Abort System abort and jettison motor performance
- Calculated Ares-I Launch Stand plume induced pressure and heat transfer loads
- Reduced CLV J-2X scissor duct grid generation by factor of 4 using an improved platform for grid generation
- Performing multi-phase simulations of draining tank flows for CLV Upper Stage tanks and first and Upper stage RCS engine tanks
- Defining maximum heat flux for J-2X injector baffles and J-2X main combustion chamber barrel
- Developing methods to define maximum heat flux and calculate thermal margins for J-2X, CECE, and RS-68 TCAs
- Developing hybrid CFD-DSMC code for Orion heat load predictions
- In response to a CLV need, CUIP has initiated seed tasks in the solids propulsion area...developing technique to dramatically reduce the cost of propellant characterization

CUIP also impacts Space Shuttle, an **operational** system

- Lift-Off Debris analysis
- ET LH₂ Tank Pre-press issue (pre-STS-114)
- STS-117 Poppet valve Chrome flake in GOX pressline to LOX tank diffuser
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