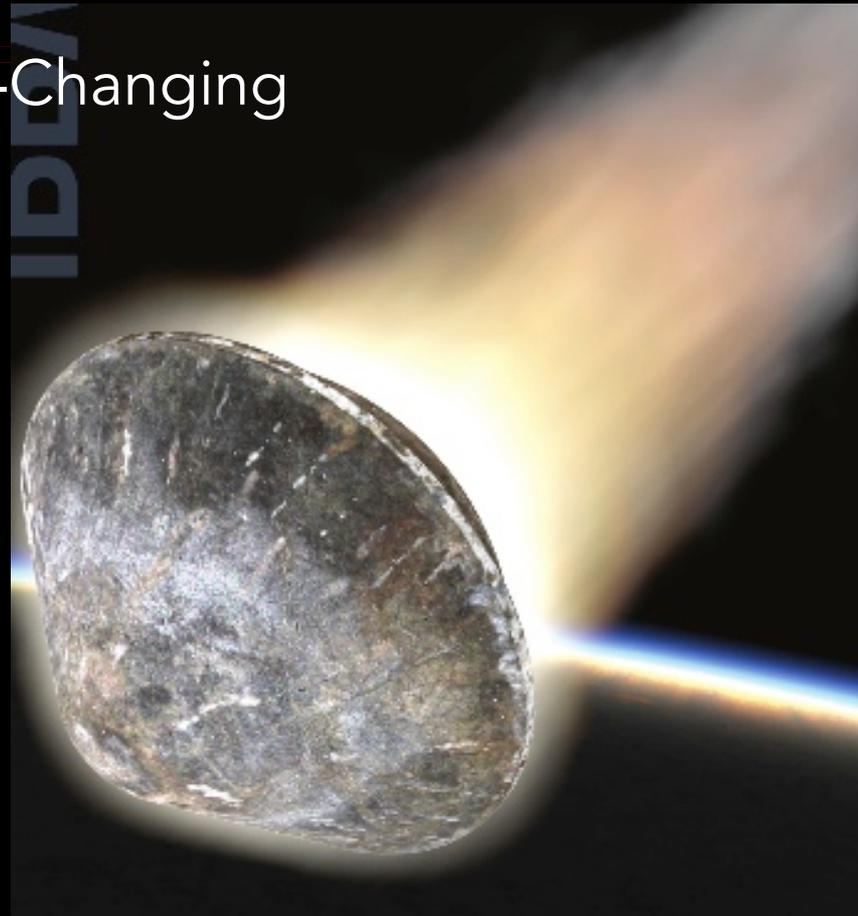




# Development Challenges of Game-Changing Entry System Technologies From Concept to Mission Infusion

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# Motivation



- Share our experience in developing four entry system technologies and the lessons learned.
  - These technologies are primarily funded by the GCDP
    - SMD and Orion have been partners and stakeholders
  - Success and mission infusion in some and challenges with others.
- Observations on fostering a culture of success and on constraints that limit greater success are addressed
- It is hoped that our experience and observations can help current and future technology development projects.



# Acknowledgements



- There are many, many to thank and it is a long list
- First and foremost are those that address each and every technical challenge that we faced and will continue to face.
  - These are folks at NASA Centers (Ames, Langley, JSC, Goddard and JPL), and Industrial partners – Vendors (BRM, TRL, SDC, FMI, TVA)
- Test facilities and the folks that took the steps needed to make each test a success ( JSC, ARC, AEDC, LHEML)
- Leadership and Management at STMD, SMD, Orion/LM, NASA Centers and JPL, GCDP, SBIR Program, NASA Ames Center Innovation Funds Program
- Finally community support and Advocacy
  - VEXAG, OPAG, MEPAG

# Technology Development at NASA (2010-2012)



- Bobby Braun was appointed as the NASA Chief Technologist (Feb., 2010)
  - Recognized very little seed corn is left at NASA and new investments have to be made
- Space Technology Mission Directorate created (Feb., 2013).
  - Vision: “STMD rapidly develops, demonstrates, and infuses revolutionary, high-payoff technologies.”
  - Game Changing Development Program:
    - “With Game-Changing, we’re looking at a two-year process of getting the TRL from 3-5” – GCD Program Goal



**“We intend to take considerable risks’ to innovate” – Bobby Braun**

# Considerations for Game-Changing Technology Development Funding (May 2015)



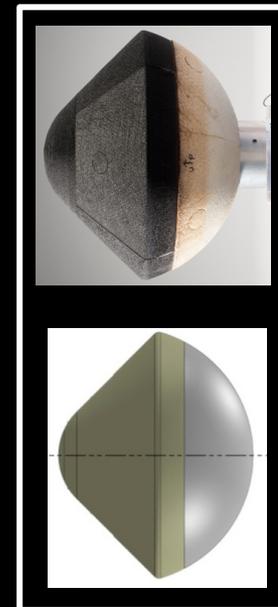
Appropriateness	Is this a broad technology and not engineering/research?
Relevance/Alignment	Is the technology aligned with Technology Roadmaps, Decadal Surveys?
Value Proposition	What is the ratio of the potential benefits of the technology to the cost to mature the technology?
Leveraging/Partnering	Is the stakeholder/partner contributing resources?
Customer Advocacy	Do potential end users recognize the benefit and support the activity?
Development Plan & Infusion Potential	Is the activity well-planned, with appropriate schedule, budget, advancement milestones, KPP's, and options?
Acquisition Strategy	Is the proposed acquisition strategy the most effective strategy to mature the technology?
Timeliness	Is it critically important that this investment be initiated right now?
Maturity	As a general guideline, GCD initiates investments at a TRL = 3 and matures the technology to TRL = 5.

**Many factors used during selection evaluation as well as in continuation decisions have evolved over time.**

# A Synopsis of the Four EDL Technologies



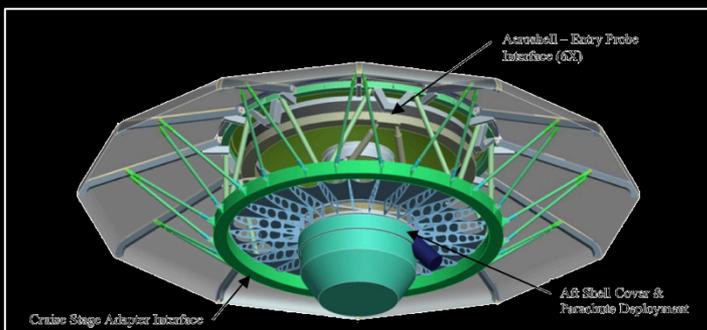
	Background	Technology	Attribute
<b>Conformal</b>	MSL PICA Experience	Ablative Material	Enhancer
<b>3-D MAT</b>	Orion EFT 1 EM1 Need	Multi-functional Material (Ablative TPS and Structure)	Enabler Time Critical
<b>HEEET</b>	Carbon Phenolic atrophy; Saturn, Venus, Higher speed Sample Return	Heat-shield and ablative TPS; Integrated sub-system	Enabler Time Critical
<b>ADEPT</b>	Human Mars; Venus and Outer Planets	Novel Entry System	Game Changer Time Critical ?



Post-tested Arc-  
Jet Test Article

Flight Article

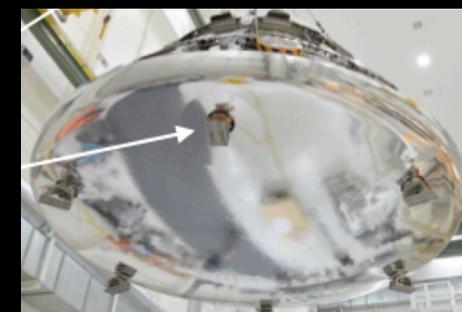
Conformal



ADEPT



HEEET



3-D MAT



# Observations and Lessons Learned

# Focus the Development on Near-term Mission Needs – Critical for Mission Infusion



Establishing Mission Usage Agreement and Meeting the Commitment are Critical to Sustaining Support

- Mission usage agreement with one or more user(s) or agreement with Mission Directorates as early as possible
  - Identify near term mission(s) and establish requirement early and working with users
  - Perform system and trade studies and establish technology benefits early.
  - Establish success criteria - Define TRL and Maturation milestones clearly and develop the project plan based on the user agreement
  - Independent Review and reporting of progress

Technology	Comment
Conformal	Mission pull (for large scale applications) lacked. NRSAA with a small company at small scale.
3-D MAT	Mission usage agreement established early and Orion needed the technology. Time critical
HEEET	SMD-PSD as partner
ADEPT	HEOMD. Near term mission pull for Venus (NF) vanished with the developmental success of HEEET.



# Communicating Risks and Rewards



Frequently communicate progress as well as challenges.

## New technologies have significant unknown risks

- Risk is both perceptual and real
- Competed missions and directed missions both are concerned with infusability
  - Risk posture and schedule needs change.

## Mission critical/enabling technologies have higher perceptual value

- Informing mission planners and scientists crucial to maintaining the advocacy

	Comment
<b>Conformal</b>	Target 250 W/cm <sup>2</sup> – Current capability ~1800 W/cm <sup>2</sup> ; ~ 40% mass efficient compared to PICA. Lack of partnership with near term missions makes large scale development a challenge. Ideal for a small company to license the technology. Small Probe Flight Test in the near future.
<b>3-D MAT</b>	Time critical and no alternate solution. Mission need and timely development helped achieve mission infusion.
<b>HEET</b>	Periodic briefing to OPAG, VEXAG, SMD-PSD, STMD, GCDP and NF/Discovery proposal teams. Accomplishments to-date show significant robustness and mass efficiency.
<b>ADEPT</b>	Human Mars a viable longer term target. Venus NF was a near term target. Development of HEET as a competing concept. Nano-ADEPT has high potential use.

# Partnerships for Project Success



## Well Developed and Managed Partnerships Drive Down Risks

Technology	Comment
Conformal	TVA as a partner brings flight data.
3-D MAT	Orion was a funding partners. Engaging BRM and San Diego Composites early in the development resulted in mission infusion success.
HEEET	OPAG/VEXAG community support and recommendation to SMD-PSD. SMD-PSD support during formulation and project execution phase. Unanimous support by APL, Goddard and JPL.
ADEPT	Early focus on Venus – excellent partnership and advocacy. BRM and Thin Red Line as partners via SBIR. Flight Test Program partnership allows leveraging.

- Engage industrial partners as early as possible.
- Mission directorates as partners – Skin in the Game.
- Stakeholders as Partners -
  - NASA’s Small Business Innovative Research (SBIR) program
  - Sub-Orbital Flight Test program
  - Communities such as VEXAG and OPAG promote mission benefits
  - NASA Centers, JPL, APL - resources and support reviews



## On Technology Maturation Timeline: Program Goal vs. Project Reality



- Goal of (2-3) years for GCDP Projects, while commendable, is rarely realizable.
  - 3-D MAT is an exception, but still needed schedule extension.

Technology	Planned	Executed	Comment
Conformal	2+	5+	Annual budget - uncertainty and unanticipated reduction
3-D MAT	18 months	30 months	Technical Challenges in weaving and resin infusion
HEEET	4 years	(4+) < 5	Progress is nearly on target – 3 of 4 year project
ADEPT	3 years	5 +	Annual budget uncertainty and unanticipated reduction

Truly game-changing technologies with uncertain challenges have uncertain schedules

- We plan for known risks – discovery of new risks requires additional time
- Fluctuating resource commitments adversely impact maturation time line.



# Concluding Remarks



Technology Organizations must and need to take risks and make sustained commitment:

- Genuine Game Changing Technology development is extremely challenging
  - High Reward and High Risk ; Longer development time; Low end-user commitment;
- Technologies that are focused on near term missions have a better chance
- In-depth pre-formulation and sustained resource commitment is needed

Achieving TRL 6 is only the end of the beginning

- Success is Mission Infusion and sustained commitment is needed by many
  - Technology must be sustained well beyond TRL 6
  - How to “Park” the technology once matured to TRL 6 ?
    - Requires commitment from multiple organizations (STMD.,SMD, NASA Centers) .



Thank you