Globalization of Materials R&D: Implications for Government Agencies

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Case Study:
NASA and the development of materials for Thermal Protection Systems (TPS)

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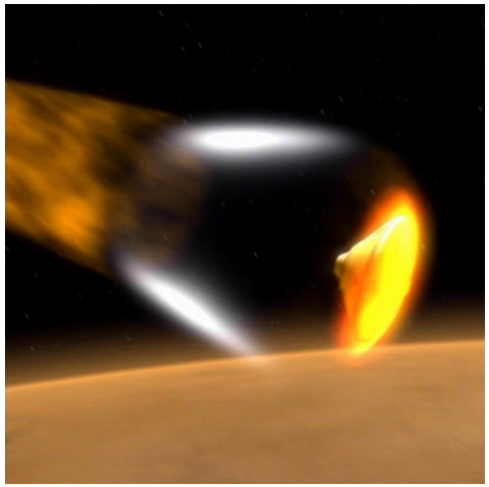
Outline

- Materials R&D for Thermal Protection Systems (TPS)
  - Reusable materials
  - Ablative materials
  - Export controls
  - Test facilities

- The Globalization of Space
  - Recent international achievements
  - New US vision for space exploration
  - Reactions of government space agencies

- Test case for the new environment
  - Issues for globalization of TPS materials R&D

Two Classes of TPS Materials



MER

Space Shuttle

- TPS materials fall into two broad categories:
  - **ablative**
  - **reusable**
- The possibilities for international cooperation are very different for the two classes of materials

Reusable TPS Materials

- NASA has long history of technology sharing in the area of reusable TPS technology
- Shuttle materials broadly described in open literature
- Europeans took advantage of what NASA put in the public domain
- Hermes project (planned as the EU space shuttle) was a flowering of that effort
  - materials qualified for Hermes were very similar to Shuttle materials
- Hermes effort became the basis for ongoing TPS development work in Europe
- X-38: European materials were selected

However…

The Administration shall provide for the widest **practicable and appropriate** dissemination of information concerning its activities and the results therof…

National Aeronautics and Space Act, 1958 (as amended)

Ablative Materials

- Special category in the US: ‘dual-use materials’
- Any potential for military application will prevent disclosure
- Onus is on the discloser
- Export license from State Dept required for disclosure of any information
- Need to convince Missile Control Regime (MCR - military attachment to Dept of State) that materials in question do not have a dual-use capability
- Such permission not easily obtained, but not impossible:
  - e.g., demonstrate that the ablative material in question does not have the heat flux capability that would be required for military applications

International Traffic in Arms Regulations (ITAR)

- Technical data is an exportable commodity under ITAR regulations

  - Information required for the design, development, production, manufacture, assembly, operation, repair, testing, maintenance or modification of defense articles. This includes information in the form of blueprints, drawings, process specifications photographs, plans, instructions, and documentation.

- What is an export?

  - Transfer of US origin goods, services or technology/technical data to a foreign person, entity, or destination whether in the US or abroad

Arc Jet Test Facilities

- **Necessary** for all TPS development
- US operates three complexes
  - one high pressure/low enthalpy facility suitable for military applications for DoD
  - two low pressure/high enthalpy facilities at NASA suitable for space applications (Ames and Johnson Space Center)

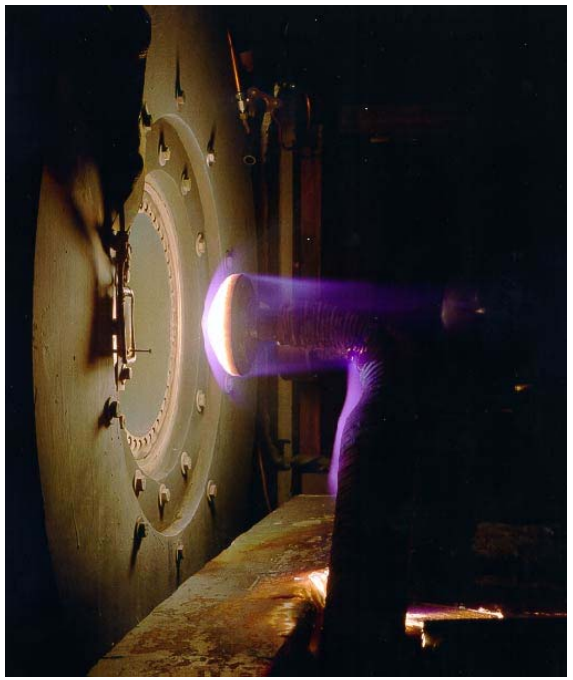
Arc Jet Test Facilities

- Successful testing is a highly complex activity, requiring aerothermal specialists, skilled at both predicting flight conditions and tailoring a test program to best represent those conditions

- NASA recognizes such facilities are essential to the maintenance of a core competency in ablative and reusable TPS development for future missions

- Europeans had several low-power facilities
  - not adequate for serious TPS development and design validation
  - need for larger facility to support Hermes program

Ames Arc Jet Test Facilities



Ames IHF Facility, one of several in the Arc Jet Complex

- Ames arc jets have played a role in the development of almost every NASA TPS since the Apollo era

Scirocco Arc Jet Test Facility

- New facility operated by the Italian and European space agencies, CIRA and ESA (initially funded by Hermes program)
- Design based on Ames arc jets:
  - arc heater and nozzle designed and fabricated using US technology
  - required export license
  - license obtainable ONLY because facility is low pressure, useful for simulating space conditions, unlike the high pressure DoD facility

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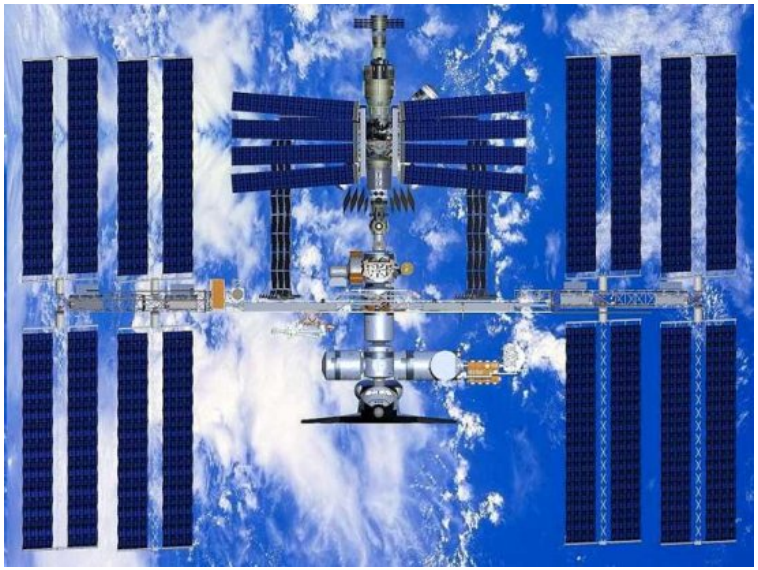
‘Space is a global industry’*

Huygens



International Space Station

Shenzhou launches taikonaut

*Daniel Sacotte, ESA , to the Commission on the Implementation of US Space Exploration Policy May, 2004

New US Vision for Space Exploration

- 'A Sustained and Affordable Human and Robotic Partnership to Explore the Solar System and Beyond'

- 'Extend human presence across the solar system, starting with a human return to the Moon by the year 2020, in preparation for human exploration of Mars and other destinations'

- 'The vision I outline today is a journey, not a race, and I call on other nations to join us on this journey, in the spirit of cooperation and friendship'

- George W Bush, January 14, 2004

Aldridge Report*

- The Commission finds that international talents and technologies will be of significant value in successfully implementing the space exploration vision, and tapping into the global marketplace is consistent with our core value of using private sector resources to meet mission goals

  Finding 6

- The Commission recommends that NASA pursue international partnerships based upon an architecture that would encourage global investment in support of the vision

  Recommendation 6.1

*President's Commission on Implementation of US Space Exploration Policy

US National Interest

The fundamental goal of this vision is to advance US scientific, security, and economic interest through a robust space exploration program

Admiral Steidle, Leader Led Workshop, ARC December, 2004

Prior to entering into government-to-government agreements, the US must first determine its own requirements, expectations, milestones and risks. It must also determine what part of its national industrial base it must protect and what technologies it is prepared to transfer to the international partners.

Report of the Aldridge Commission

I think it's very much going to be a US-led endeavor. That's our intent. And, again, much of what we have been directed and what the president envisions we do is to achieve this set of American, US Exploration objectives. To the extent we can do this cooperatively and in partnering with international participation, we are encouraged to do so.

NASA Administrator, Sean O'Keefe

Government space agencies convene to discuss cooperation

- In November 2004, NASA invited space agencies from around the world to an International Workshop on Creating New and Sustainable Space Exploration

- Attendees included the space agencies of Canada, China, EU, France, Germany, India, Italy, Japan, Russia, UK

- Workshop goals and objectives:
  - Provide a forum for NASA and international space agencies to exchange information on their individual plans for human and robotic exploration of space

  - Allow discussion of NASA and international space agency capabilities and areas of interest with regard to cooperation in exploration systems

  - Identify appropriate mechanisms for follow-on discussions

Cautious Reception

- 'The contradiction between the announcements for a strong national US program and the promotion of international cooperation fosters reservations…Germany might take a rather cautious position with respect to participation at a substantial level.'

  Dr Kai-Uwe Schrogl, German Aerospace Center (DLR)

- 'We recognize this process is necessary to ensure the protection of certain technologies. Proper planning can help to alleviate some of the burden associated with export control. Restriction on the discussion of the detailed design data and detailed definition of sub-systems is not the desirable approach; but it is manageable.'

  EADS Center for Strategic and International Studies (on ITAR issues)

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ESMD* acquisition strategy

- NASA has reorganized around the exploration vision and is changing the way it does business
- July 04 released Extramural BAA
- 3700 NOIs received; downselect to 500 full proposals;70 projects selected
- **An award which includes TPS materials development was made to an EU-led partnership with NASA and US industry**
- 1st Space Exploration Conference:Jan 2005
- RFP for development of the Crew Exploration Vehicle:March 2005

* Exploration Systems Mission Directorate

Test case for the new environment

- The award to the EU-led team is valued at up to $40m
  - EU/NASA/Industry cooperative group
  - Materials in question will certainly raise ITAR issues
    - composition and processing of dual-use materials
    - detailed system design
    - analysis codes

- Implementation will test how the drive towards internationalization and commercialization will be reconciled with security concerns

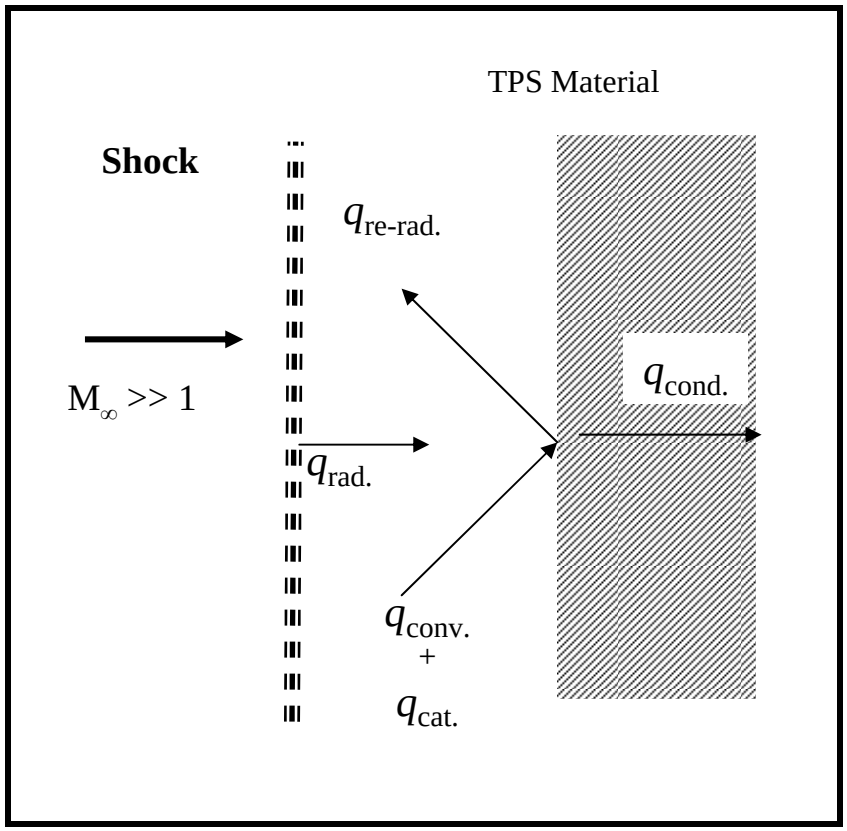
- Need to negotiate with care to maximize the science and technical output while complying with ITAR controls

Conclusions

- Global collaboration in space materials is here and will continue
- NASA has contributed to the international spread of TPS materials development
  - Sharing reusable technology
  - Design and fabrication of essential test facilities
- NASA's goals of internationalization and commercialization of the technologies for the exploration vision will certainly promote new opportunities for global participation
- New TPS materials are enabling technologies for realization of US vision for space exploration
  - It remains to be seen how international projects will proceed under the new vision, but awareness of the issues and careful planning are essential for successful global cooperation

Reusable TPS

Reusable TPS systems are designed to reject as much heat as possible and conduct as little heat as possible in order to meet the bond-line temperature requirements with minimal heat-shield mass. Low catalytic efficiency, high emissivity and low thermal diffusivity are desired in designing a TPS system.



- High emissivity coatings increase the re-radiated heat-flux and thereby reduce the heat-flux to which the material must respond:

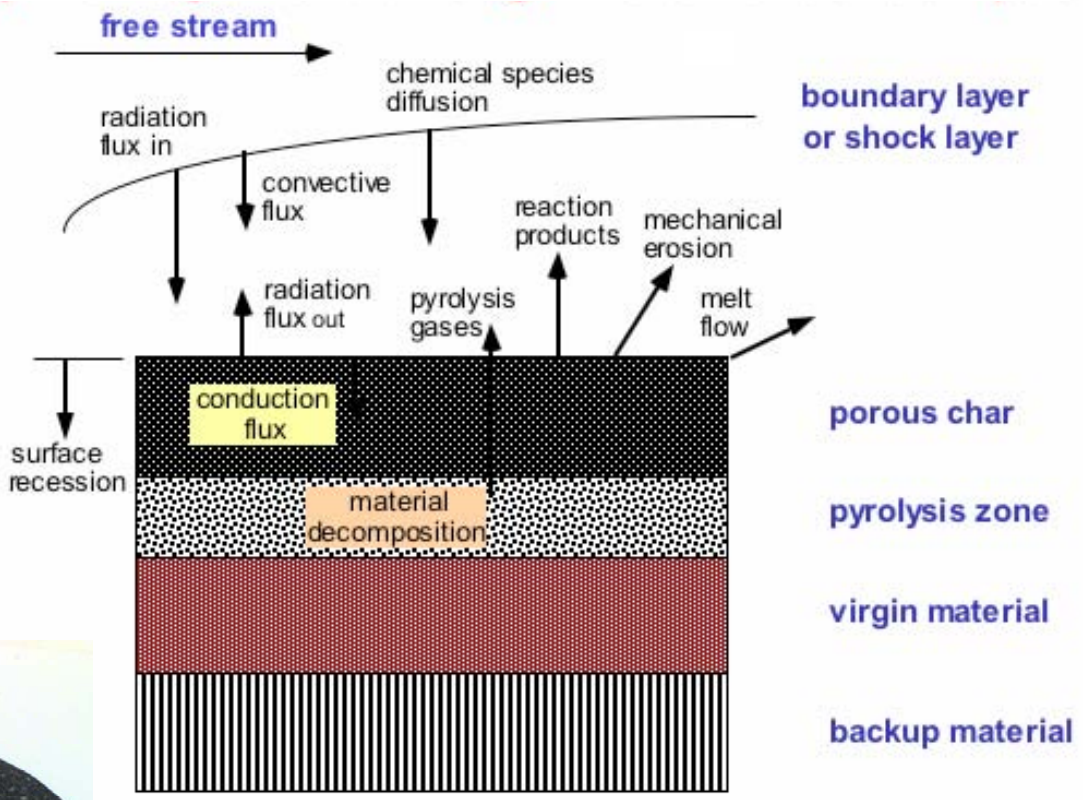
$$q_{\text{re-rad.}} \quad _w \; T_w^4, \; where \quad _w \quad emissivity$$

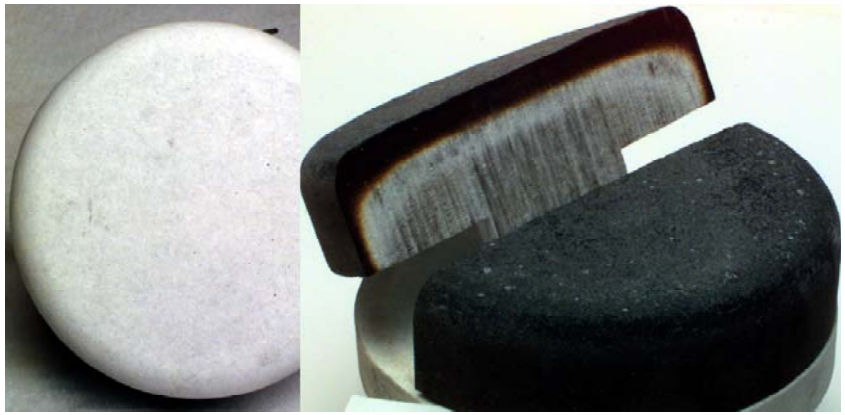
- Coatings with low catalytic efficiency reduce the release of chemical energy near the surface, thereby reducing the heat-flux at the wall
- Conduction within the TPS material depends on material properties: thermal diffusivity (***K***), density(, thermal conductivity(***k***) and specific heat (***Cp***)

$$Thermal\ Diffusivity, K \quad k / C_p$$

Charring Ablator Heat Dissipation

- In-depth pyrolysis and transpiration cooling by pyrolysis gas
- Blockage of convective heating by pyrolysis gas injection, and thickening of the boundary layer
- Re-radiation from surface char
- Endothermic consumption of surface material





Source Documents

- Exploration Vision
  http://exploration.nasa.gov/documents/vision.html
- Aldridge Commission Report
  http://govinfo.library.unt.edu/moontomars/
- Exploration International Workshop, November 2004
  http://exploration.nasa.gov/documents/explorationworkshop.html
- Administrator O'Keefe quote in presentation by J. Logsdon, Space Policy Institute, GWU
  http://www.asaspace.at/events/download/AlpbachTechnologieForum2004/(Logsdon)%20How%20does%20the%20United%20Stats%20View%20European%20Space%20Developments.pdf
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