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Fire Prevention, Detection, and Suppression

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NASA John H. Glenn Research Center

Workshop on

Strategic Research to Enable NASA's Exploration Missions

June 22 - 23, 2004
Marriott Downtown at Key Center
Cleveland, Ohio USA

Bioastronautics Initiative - History

- **In mid-1999, the Space and Life Sciences Directorate at Johnson Space Center was challenged to develop a new paradigm for NASA human life sciences**
  - Space Medicine
  - Space Biomedical Research and Countermeasures
  - Advanced Human Support Technology
- **A new thrust - *Bioastronautics* - was formulated with a budget augmentation request**
- **Objective:**
  - Expanded extramural community participation through the National Space Biomedical Research Institute
  - Initiated the detailed planning and implementation of Bioastronautics
    - *An Integrated Approach to Ensure Healthy and Safe Human Space Travel*
    - *Assist in the Solution of Earth-based Problems*

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Bioastronautics Initiative

- **Builds upon previous and ongoing work**
  - A significant amount of fundamental knowledge has been created through ground and flight research
  - Apply this knowledge base to applications and solutions which will provide *safer human operations in space*
- **Utilizes new research resources**
  - ISS/STS research opportunities
  - Ground analogs
- **Leverages new and unique capabilities**
  - Scientific community to focus on NASA issues
  - Transfer knowledge to Earth based problems
  - Cooperate with other Federal Agencies
  - Develop new technologies
    - smart medical systems
    - biologically-inspired technologies
    - fire protection

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NASA Bioastronautics Initiative – Combustion Science

- ***Substantially improve spacecraft fire safety***
  - $1M per year for four years (initial funding level)
  - Grant-based through NRAs and directed research
- **Fire safety practices and procedures**
  - ISS and Shuttle operations
  - Prolonged human-crew missions in Earth orbit and beyond
  - Lunar and/or Martian habitats
    - In-situ resource utilization
    - Propellant manufacture and storage

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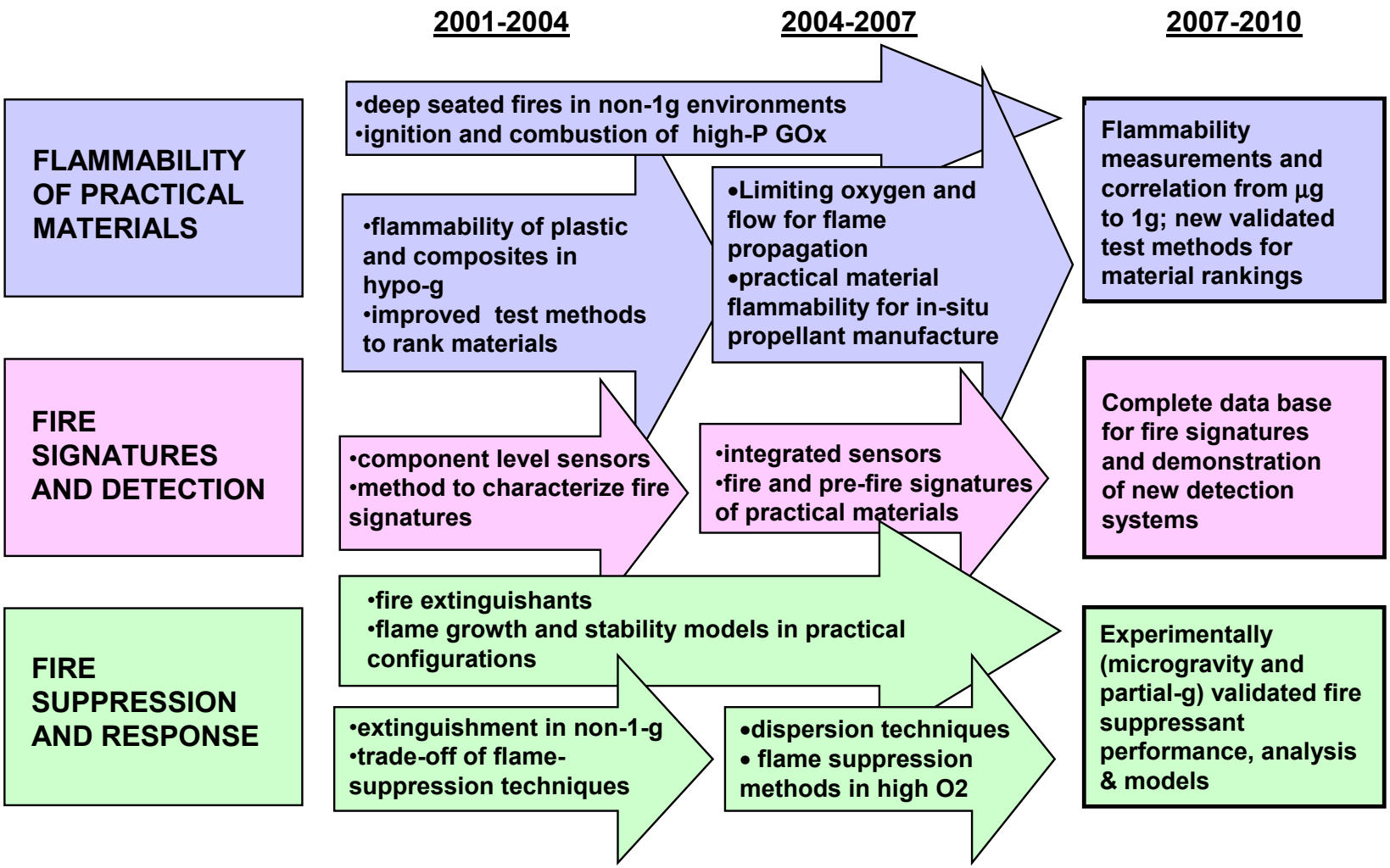
Spacecraft Fire Safety Research Roadmap



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Microgravity Combustion Science Program

- 99 NRA – Bioastronautics
  - **Test methods for material flammability (2 GRD)**
  - **Smoldering/fire initiation (FLT)**
  - **Fire suppression (2 GRD)**
  - **Fire signatures and detection (FLT)**
- 01 NRA
  - **Fire signatures in reduced gravity (GRD)**
  - **Fire suppression (4 GRD)**
- 02 NRA – Human Research Initiative
  - **Fire suppression (2 GRD)**
  - **Fire detection (1 GRD)**
  - **Large-scale modeling (2 GRD)**

Combustion Integrated Rack (CIR) Launch: Oct 2006

Microgravity Science Glovebox (MSG) in the Destiny laboratory on the ISS (Astronaut: Peggy A. Whitson)

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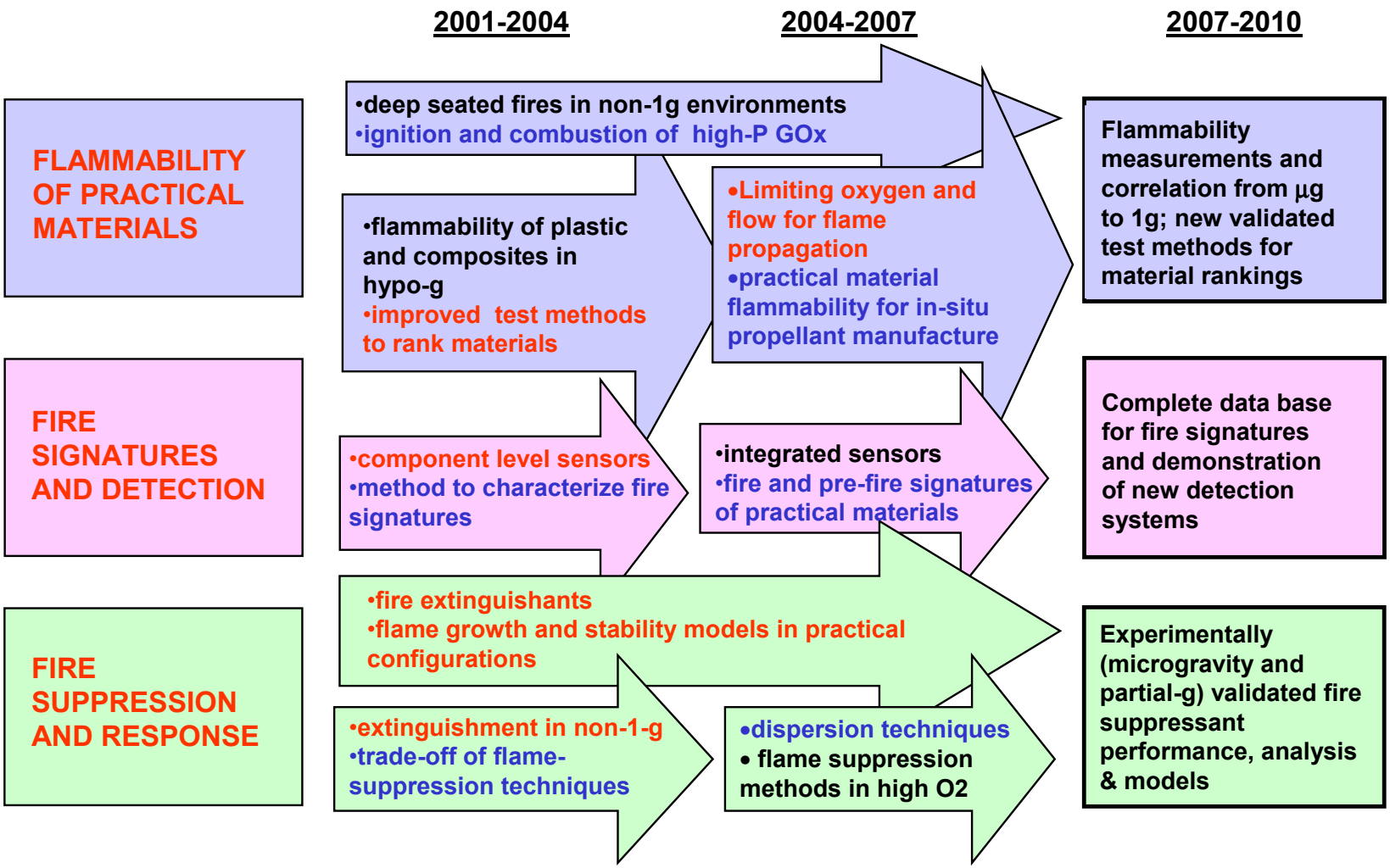
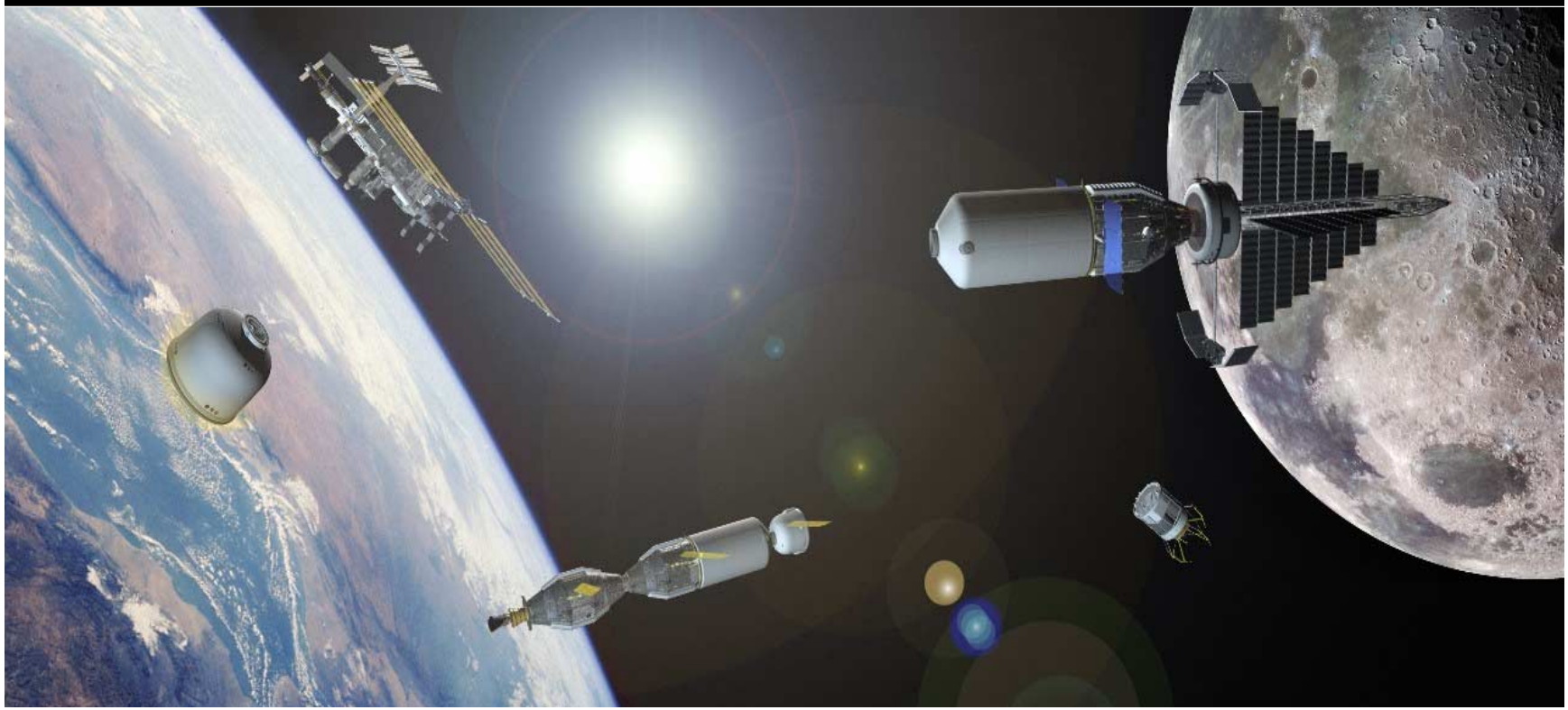
Spacecraft Fire Safety Research Roadmap



Vision for Space Exploration

"This cause of exploration and discovery is not an option we choose; it is a desire written in the human heart." – President Bush



Vision for Space Exploration

- **Pursue Compelling Questions**
  - Exploration of the solar system will be guided by compelling questions of scientific and societal importance.
  - Consistent with the NASA Vision and Mission, NASA exploration programs will seek profound answers to questions of our origins, whether life exists beyond Earth, and how we could live on other worlds.
- **For Sustainable Exploration**
  - NASA will pursue breakthrough technologies, investigate planetary resources, and *align ongoing programs to develop sustainable, affordable, and flexible solar system exploration strategies.*
  - The vision is not about one-time events and, thus, costs will be reduced to maintain the affordability of the vision
- **Starting Now**
  - *NASA will pursue this vision as our highest priority*
  - Consistent with the FY 2005 Budget, NASA will immediately begin to realign programs and organization, demonstrate new technical capabilities, and undertake new robotic precursor missions to the Moon and Mars before the end of the decade.

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Fire Prevention, Detection, and Suppression

- Office of Biological and Physical Research addressed how to develop products for The Vision for Space Exploration
- Fire Prevention, Detection, and Suppression was designated a sub-element in the Advanced Human Support Technology product line

So What?

- Outcomes are now products to support exploration missions
  - **Required for design points in the development of CEV**
- Opportunity to expand efforts in each of the areas on the research roadmap

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What Do We Do Now?

Needs

- Identify needs and issues from "customers"
  - ISS Materials and Processes
  - ISS Environmental Control and Life Support
  - ISS Fire Detection and Suppression

Potential Products

Questions

- Scientific and technological questions that must be answered to deliver the products
  - assessment of knowns and unknowns
  - incomplete answers increases risk

Concepts

- How do you answer the questions?
  - experiments (flight and ground)
  - modeling
  - system verifications

Products

- What is finally used by the customer
  - contract specification
  - design rules
  - procedures

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Issues and Needs Identified in 2001 Workshop

Fire Prevention and Material Flammability

1. Flammability at Elevated Oxygen Levels
   - Ignition mechanisms and flammability for pressurized oxygen systems was the highest priority
   - Increased O_2 fraction and sub-atmospheric pressure considered for exploration vehicles and habitats
2. Fire Scenarios for ISS/STS
   - Overheating of electrical cables, short circuits, SFOG, pressurized gaseous oxygen systems
3. Testing/Screening Methods
   - Augment existing test methods (flaming and non-flaming)
   - Improved understanding of relationship between 1-g testing and microgravity performance

"Research Needs in Fire Safety for the Human Exploration and Utilization of Space," NASA/CP-2003-212103, April 2003.

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Issues and Needs Identified in 2001 Workshop

Fire Prevention and Material Flammability

4. Development of New Materials
   - Foams, fabrics, and films
   - Radiation shielding
   - Composites

5. ISRU Processes and Storage
   - "Little activity, probably premature given absence of even long-term plans for manned missions beyond moon (if that)" 7th International Workshop on Microgravity Combustion and Reacting Systems, June 2003, Cleveland, OH

"Research Needs in Fire Safety for the Human Exploration and Utilization of Space," NASA/CP-2003-212103, April 2003.

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Issues and Need Identified in 2001 Workshop

Smoke and Fire Detection

1. Detection Systems
   - What should we detect for different types of fires?
   - Where do we put the detectors?
   - Does the detector produce frequent nuisance alarms?

2. Crew Response
   - Is detection quick enough to give the crew adequate time to respond?
   - How does the crew know where the fire is?
   - Can the senor give an indication of the danger level?
   - What capability is require for post-fire sensing?

"Research Needs in Fire Safety for the Human Exploration and Utilization of Space," NASA/CP-2003-212103, April 2003.

Issues and Needs Identified in 2001 Workshop

Fire Suppression and Response

1. Specification of the Conditions Prior to the Response
   - Simulation and verification of flow in compartments
   - Characterization of fire events
2. Evaluation of Fire Suppressants
   - Agent transport in low gravity
   - Extinguishing agent performance in low gravity
   - Gaseous and particulate emissions from fires and suppressants
3. Effectiveness of Fire Response Strategies
   - Development of fire-response concepts
     - Obscuration mitigation
   - Agent distribution requirements and behavior
   - Post-fire sampling and characterization

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Fire Prevention, Detection, and Suppression Sub-Element Products

1. Normal gravity material flammability test
   a. Candidate test(s) identified
   b. Suitable acceptance criteria for reduced gravity flammability
   c. Reduced gravity verification of normal gravity flammability test
   d. Revision/supplement to NASA-STD-6001
2. Material flammability assessment in candidate atmospheres for exploration vehicles
   – 30% O_2 fraction and 0.7 atm
   – Higher oxygen fractions for EVA
3. Design rules to prevent ignition and flame spread of practical materials
   a. Gain understanding with simple materials
   b. Relationship between the materials you can understand and materials that are actually used

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Fire Prevention, Detection, and Suppression Sub-Element Products

4. Verified models of fire precursor transport in low and partial gravity
   a. Development of models for large-scale transport in reduced gravity
   b. Validated CFD simulations of transport of fire precursors and contaminants
   c. Evaluation of the effect of scale on transport and reduced-gravity fires
5. Advanced fire detection system for gaseous and particulate pre-fire and fire signatures
   a. Quantification of pre-fire pyrolysis products in microgravity
   b. Suite of gas and particulate sensors
   c. Reduced gravity evaluation of candidate detector technologies
   d. Reduced gravity verification of advanced fire detection system
   e. Validated database of fire and pre-fire signatures in low and partial gravity

Fire Prevention, Detection, and Suppression Sub-Element Products

6. Verified design rules for reduced gravity suppressant systems
   a. Quantification of suppressant effectiveness in low and partial gravity
   b. Reduced gravity verification of suppressant system performance

7. Virtual Reality Simulations of fire scenarios
   a. Realistic visual representation of a fire environment
   b. Interactive participation in fire simulation
   c. Fire response module for crew training

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FPDS Organizing Questions

- Organizing questions were drafted in the areas of
  - Fire prevention and material flammability
  - Fire suppression and response
  - Fire detection
- Working groups were formed within the Microgravity Combustion Science Branch (NASA and NCMR)
  - Fire prevention and material flammability
    - Facilitator: Dr. Fletcher Miller
  - Fire suppression
    - Facilitator: Dr. Fumiaka Takahashi
- Purpose of working groups
  - Review organizing questions
  - Which are addressed by current experiments/hardware?
    - How well are they addressed?
  - Develop concepts for experiments that address the questions

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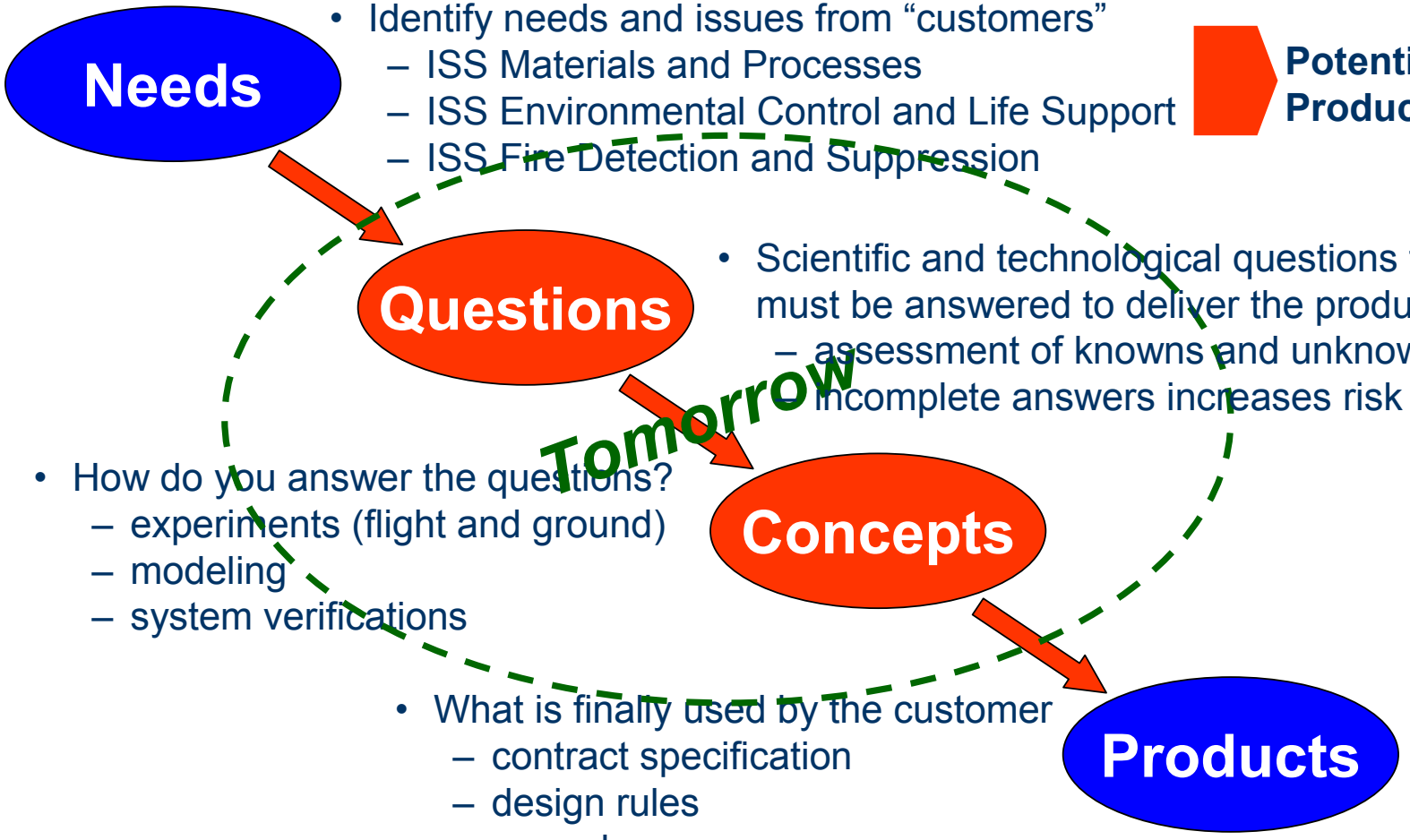
What Do We Do Now?



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What do you want from us?

Discussion, critique, and ideas

- organizing questions
- products to be delivered
- concepts of potential experiments
- research needs

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Summary

- Much has changed since January 2004
- We have the opportunity to impact the Vision for Space Exploration
  - Provide fire safe designs and countermeasures for exploration spacecraft and habitats
- The process we have been following has expanded the research plan developed at previous workshops
  - Increased scope and imposed a schedule
- We can deliver the best products through the collaboration of
  - NASA (Scientists, operations, and flight support personnel)
  - Government labs
  - Academia
  - Industry