Space and Ground Trades for Human Exploration and Wearable Computing

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General Motivation

- *What might be the space - “ground” functional distribution for Constellation/Exploration: particularly, lunar sorties, lunar outposts, and human Mars missions?*

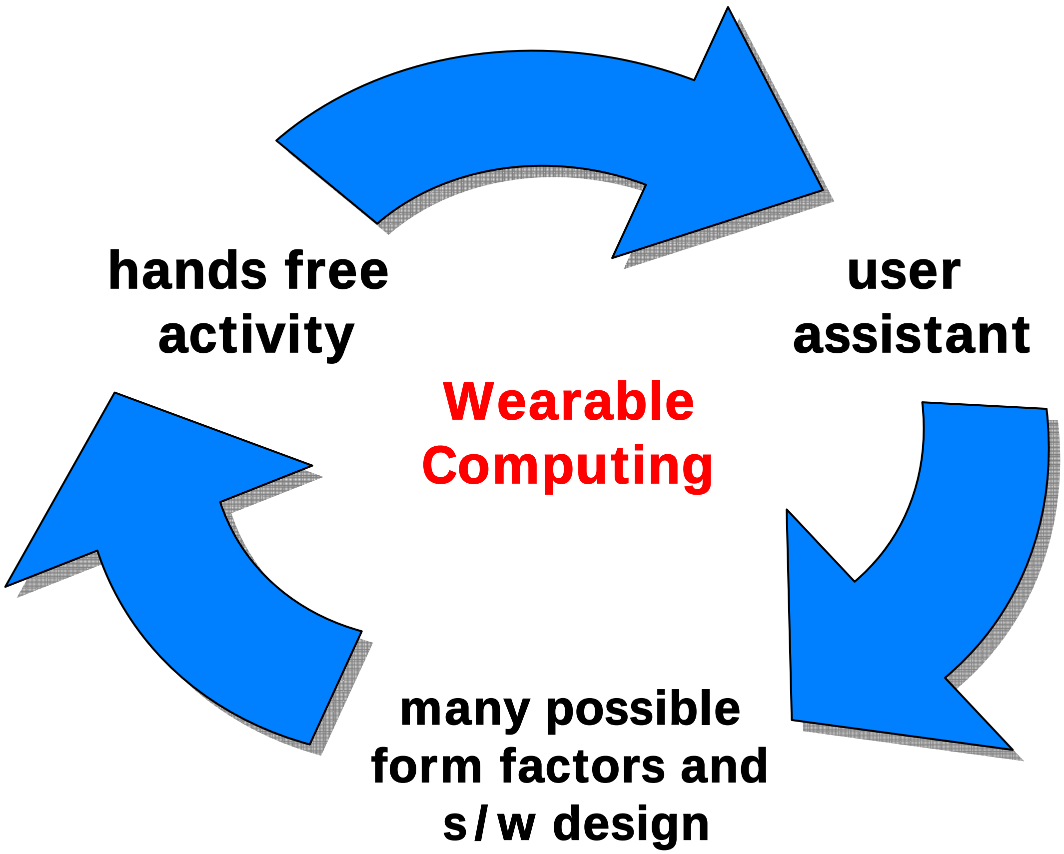
- *What are the space-ground functional distribution implications associated with “highly local” (e.g. wearable) functionality for astronauts?*

Agenda

- **Background**
  - General overview
  - Related work
- **Potential Utility to Exploration Initiative**
  - Motivation and Scenarios
  - Three Exploration Initiative Space-Ground Trade Themes
  - Role of wearable computing
- **Future Work**
  - NASA wearable computing working group (WCWG)
  - Roadmapping and formal trade studies
  - Prototyping

General Overview of Wearable Computing

Our notion of wearable computing emphasizes ***PC level processing and general purpose computing*** that allows for ***some degree of hands-free control***.



General Overview con't

Xybernaut MA-V:

- 500 MHz Intel Mobile Celeron processor
- 128 MB of RAM
- 5 GB hard drive

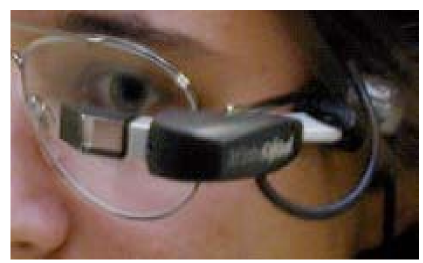
Input and Output Devices

Input devices: (Other possibilities are head and eye trackers)

microphone headset | **wrist-worn keyboard** | **camera** | **handheld trackball**

Output devices: (including earphone on headset)

flat panel display



head-mounted displays

Related Work

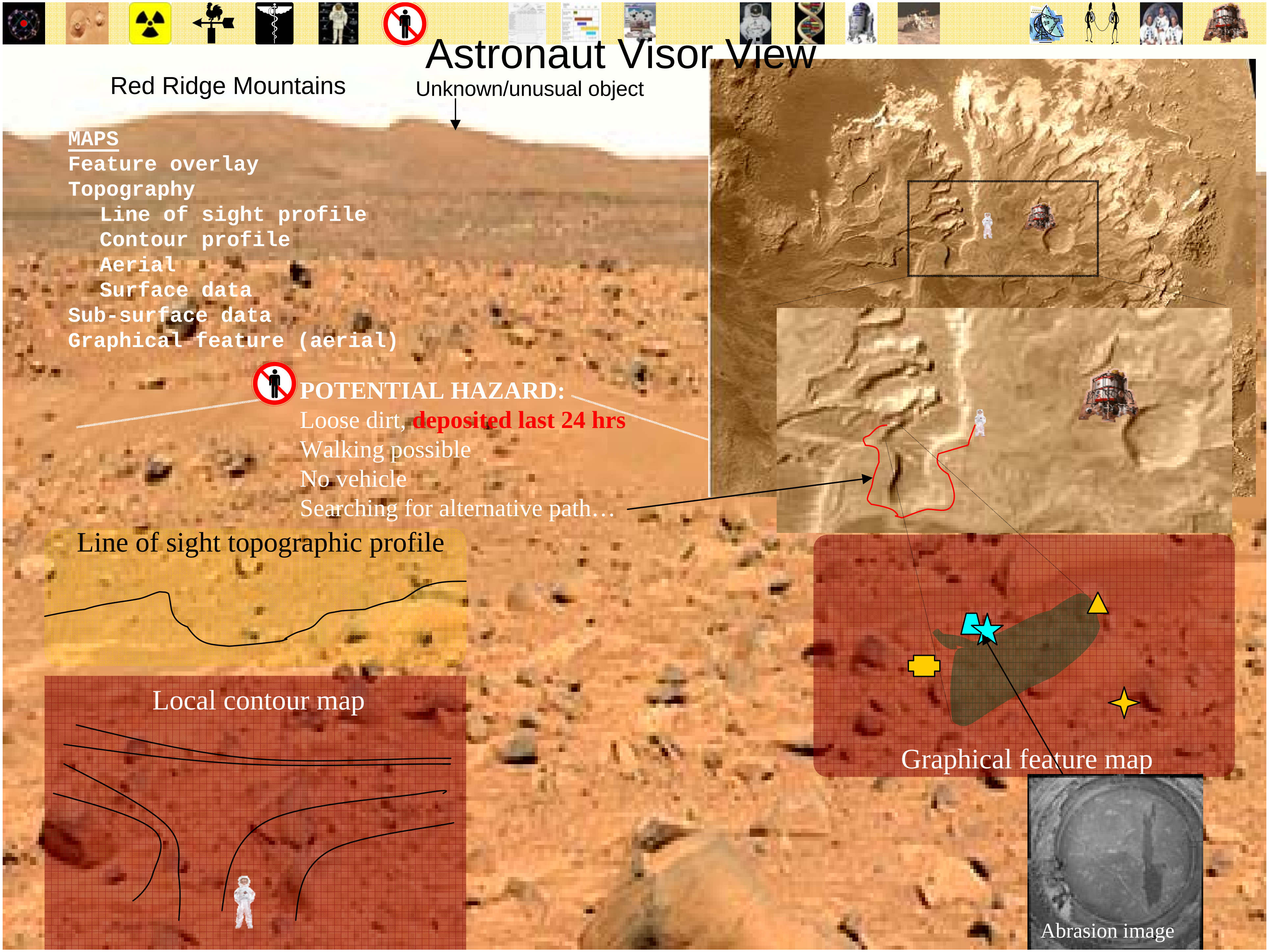
- GSFC Wearable Voice Activated Computer (WEVAC) project
- North Carolina A&T Pervasive Systems for Education Enhancement (P-SEE)
- JSC: iPAQ, TekTrak (Lunar EVA Crew Tracking), BioNet (OSI-based architecture for crew health and environment data)
- ARC: Human-robot interaction

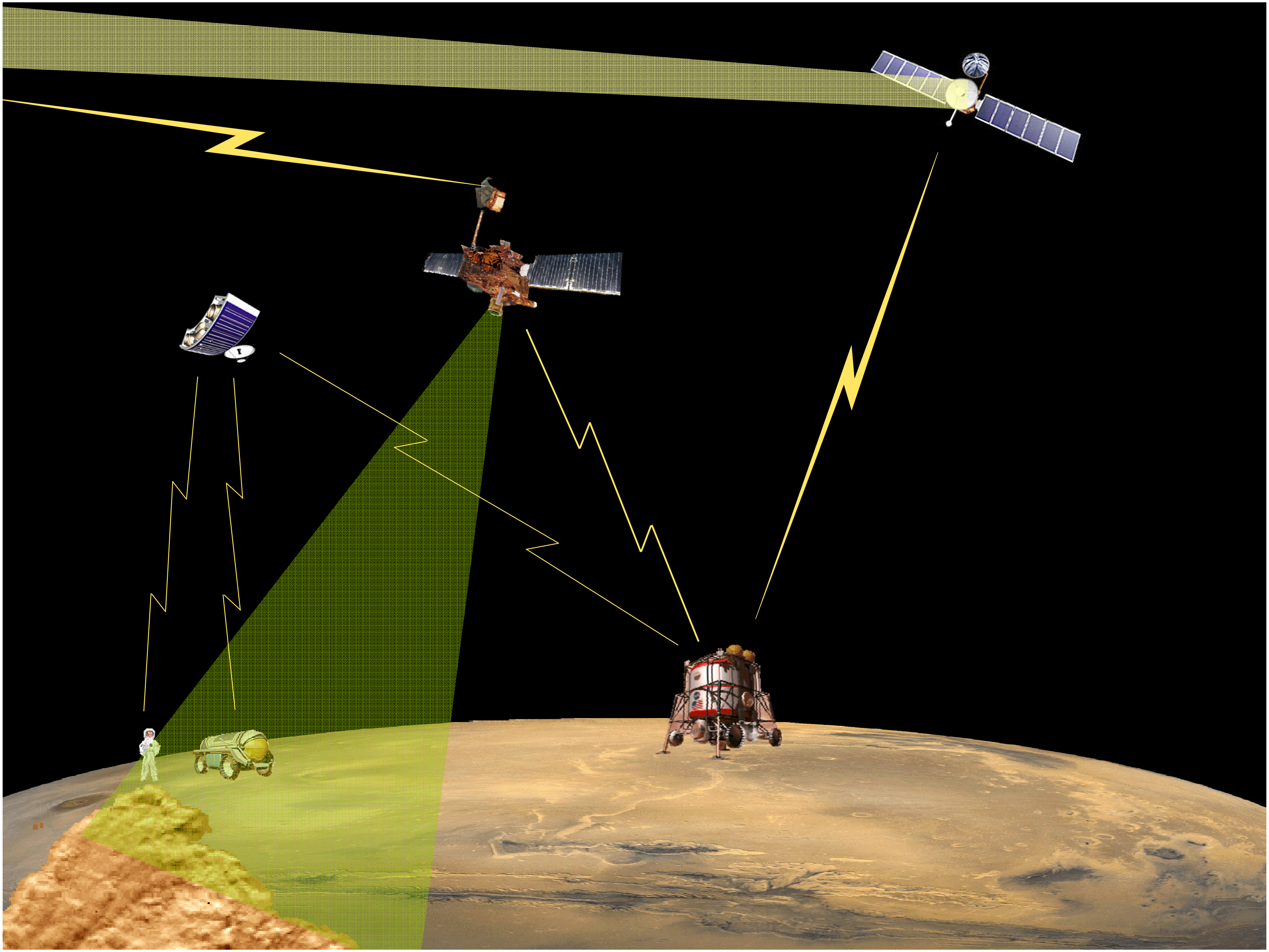
Motivation for Exploration

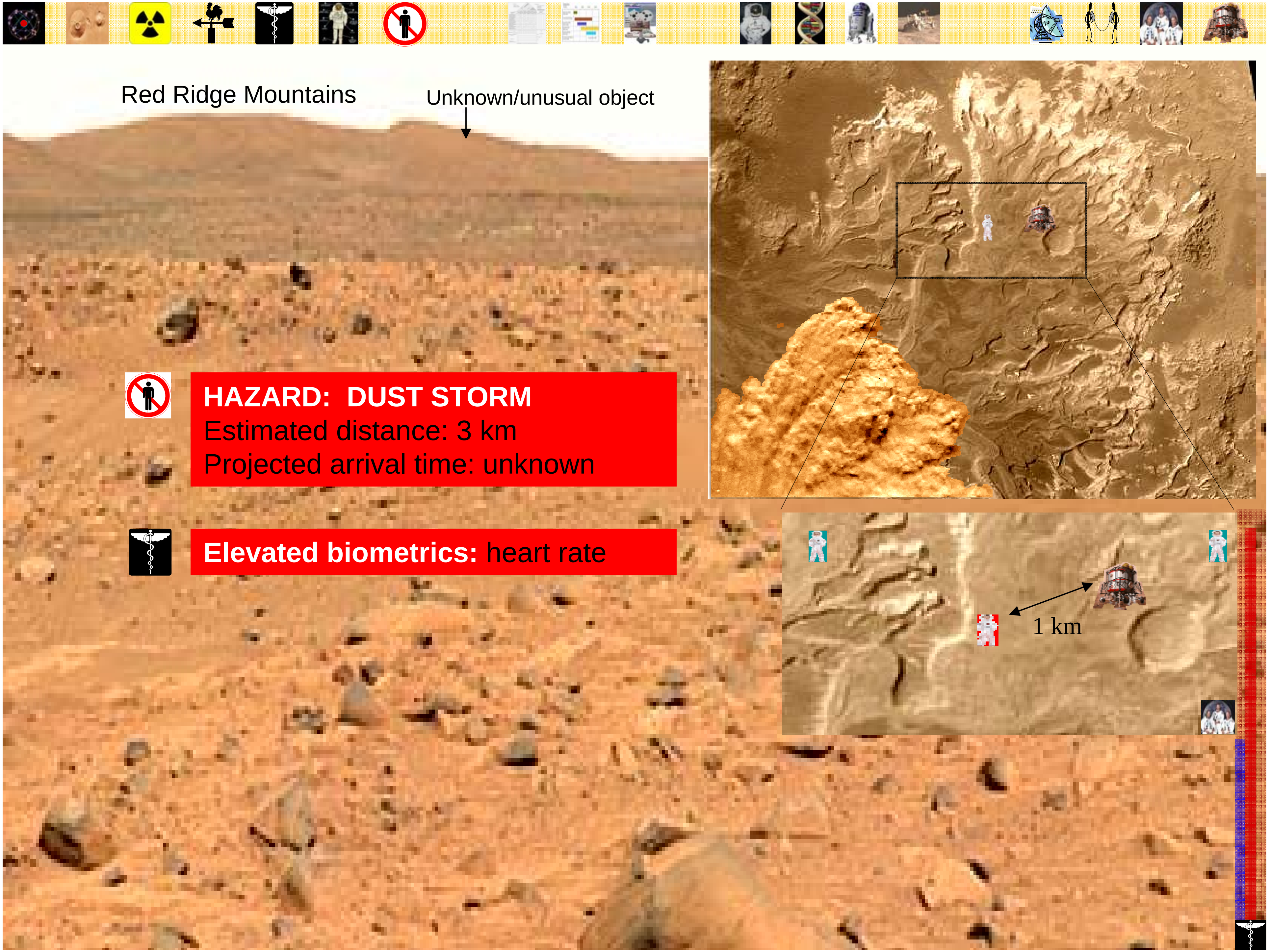
- “Explorer-centric” approach
- The ***Integrated Explorer*** should have hands-free access to all data, all the time, everywhere
- But with automated/intelligent processes to help the explorer filter and avoid overload
- Optimize explorer safety and productivity and hence help enable affordable and sustainable exploration
- *Ground support personnel can use wearable computers as they work on physical ground models while supporting space-based needs*

Scenario Categories

- **Shuttle robotics**: mobility allows for different viewing angles.
- **Station robotics**: same as above, voice navigation gives you hands free - with crew of 3, mobility helps.
- **Station inventory**
- **Constellation**: maintenance, field exploration, medical, safety


Astronaut Visor View
Red Ridge Mountains
Unknown/unusual object
MAPS
Feature overlay
Topography
Line of sight profile
Contour profile
Aerial
Surface data
Sub-surface data
Graphical feature (aerial)
POTENTIAL HAZARD:
Loose dirt, deposited last 24 hrs
Walking possible
No vehicle
Searching for alternative path…
Line of sight topographic profile
Local contour map
Graphical feature map
Abrasion image




Red Ridge Mountains
Unknown/unusual object
HAZARD: DUST STORM
Estimated distance: 3 km
Projected arrival time: unknown
Elevated biometrics: heart rate
1 km

Motivation - some specifics

- **Routine monitoring**: e.g. position, weather, biometrics, bio & systems health monitoring, self-interpretation & re-configuration - understanding and managing the space suit as a personal space habitat)
- **Maintenance information**: e.g. hab maint., field repairs of robots, transport vehicles, instruments, etc.
- **Ground truth**: e.g. check databases against real-time field data
- **Reduce mass to orbit** by eliminating the need for manuals, disks, and other cumbersome reference systems
- **Data/video capture** for science investigation, real-time assistance, lessons learned, training or safety investigations
- **Data visualization** of data, plans, navigation, timelines, etc. that provide more global data to the explorer, enabling more efficient use of time, reducing uncertainty regarding safety/route/interpretations, and facilitating coordination of multiple people, robots, and tools.
- **Resource trade-off computations**

Motivation specifics con't

- **Increase science return** and productivity by providing access to relevant information (e.g. via local data store, internet, remote specialist) during EVA
- **Crisis resolution**: e.g. lost or stuck astronaut assisted by WC
- **Hazard warning/monitoring/mitigation**: e.g. dangerous topography
- **Dynamic/adaptive planning**: e.g. dealing with recent/unforeseen events
- **Seamless situational awareness**: system knows where you are and automatically provides relevant data for that domain (e.g. greenhouse vs. control room vs. field, or low data network signal vs, higher RF)
- **Augmented reality**: e.g. "feature overlay"
- **EVA enhancement**: move pre and post EVA activities to during EVA
- **Complete integration** of WCs, robotic systems, life-support, vehicles, etc. through wireless computing, mediated by agents. E.g., C3 for networks of systems under astronaut control, automation of some CapCom functions
- **Training:** "embedded" or environment-dependent instruction - especially for manually intensive tasks

Examples of Trade Themes

1. **Redundancy**: What functions (e.g. command, data analysis) should exist simultaneously on Earth, Moon/Mars, and the human explorer?

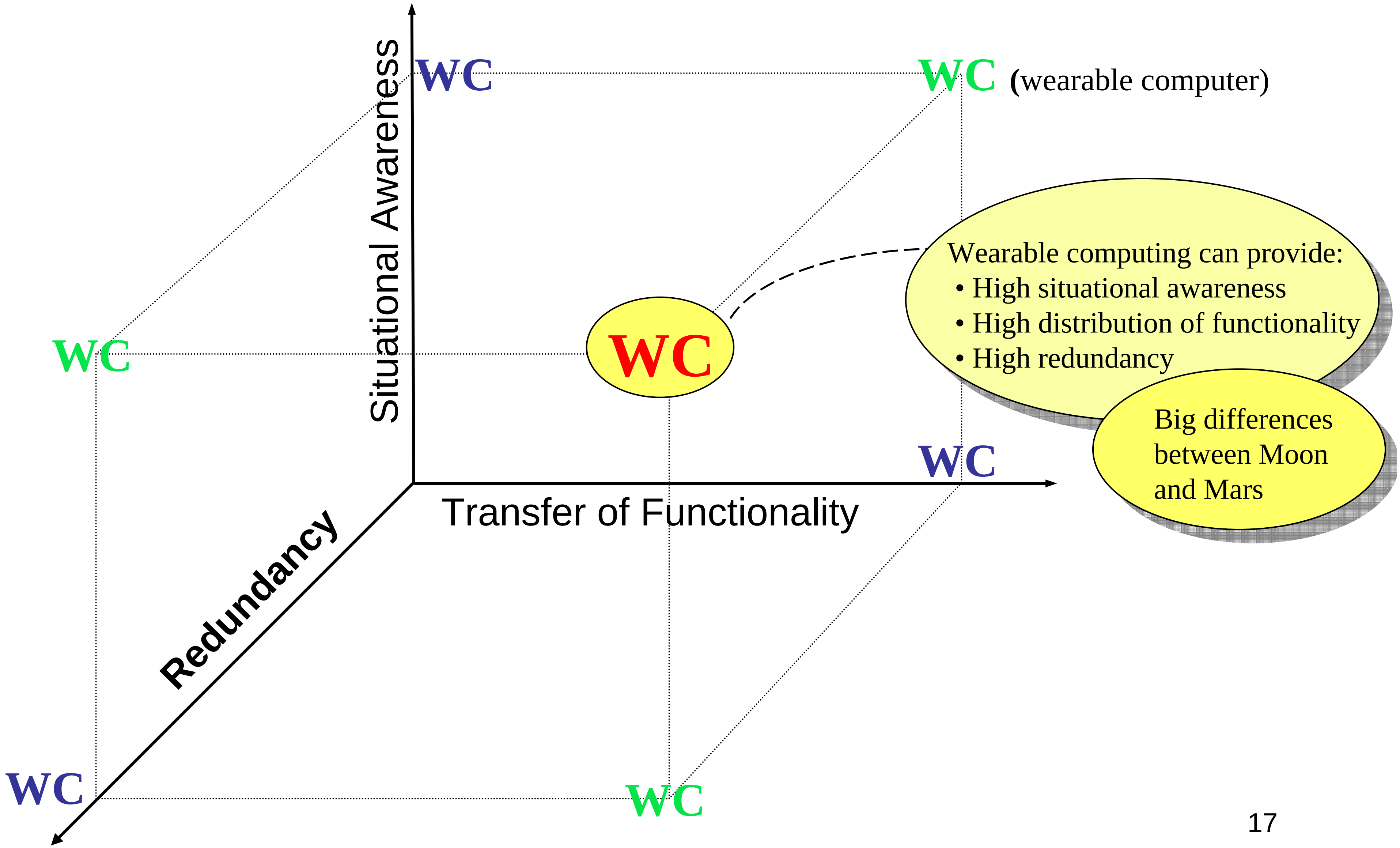
2. **Situational Awareness**: How much situational awareness (e.g. environmental conditions, biometrics, etc.) is required/desired, and where should it reside?

3. **Transfer of Functionality**: To what extent should traditional ground and space system functions be transferable among the Earth, Moon/Mars, and the human explorer?

Trade Examples

- **Redundancy**
  - Science Data processing and storage
  - Telemetry processing and storage
  - Planning and scheduling
- **Situational Awareness**
  - Biometric data processing
  - Subsurface science data (e.g. water)
  - Weather data
- **Transfer of Functionality**
  - Command and control
  - Communication configuration
  - Planning and scheduling

Wearable Computing in a Trade Space



NASA Wearable Computing Working Group (WCWG)

- Keep each other informed
- Write papers
- Develop roadmap
- Submit proposals
- Organize meetings
- Trade studies
- Prototype

Roadmapping and Trade Studies

- Programmatic and technical roadmap - e.g. mapped against Constellation development
- Formal trades studies should include explicit space ground trade recommendations and technology trades such as:
  - Highly customized suit-integration (e.g. smart fabrics, visor integrated display)
  - "wearable terminal"
  - Complete OTS wearable computer solution (minimal integration)
  - Something hybrid, e.g. OTS device with some integration and customization

Trade Studies and Prototyping

Trade studies and prototyping can be informed by:

- ***Agent-based simulations*** that models cost, operational effectiveness, and optimum ops concepts in comparison with other competing technologies
  - Quantitative assessment of costs and benefits
  - Mass savings
  - Productivity
  - Discovery/science return
  - Situational awareness/safety options
- ***The development of an integrated, wearable computer system***, based on proven application and identification of technology projections for a space-rated system
  - Demonstration and data collection of enhancements for productivity, situational awareness, etc.
  - Comparison to present EVA capabilities
  - Development of an integrated wearable computer system
- ***Suited tests***: productivity, safety, etc.