User-Centered Design and Evaluation of a Real-Time Battlefield Visualization Virtual Environment

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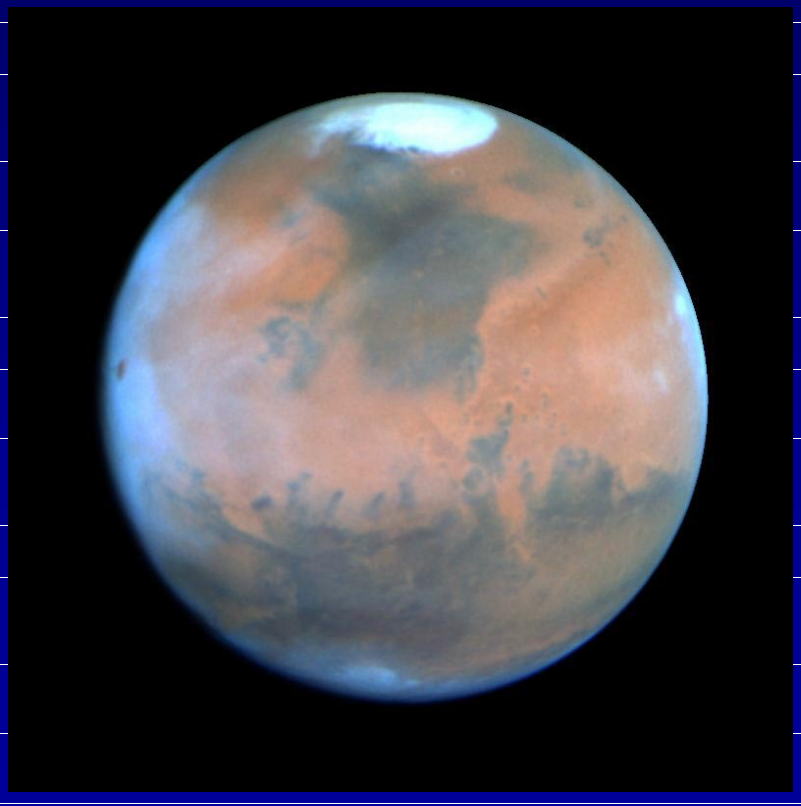
Outline

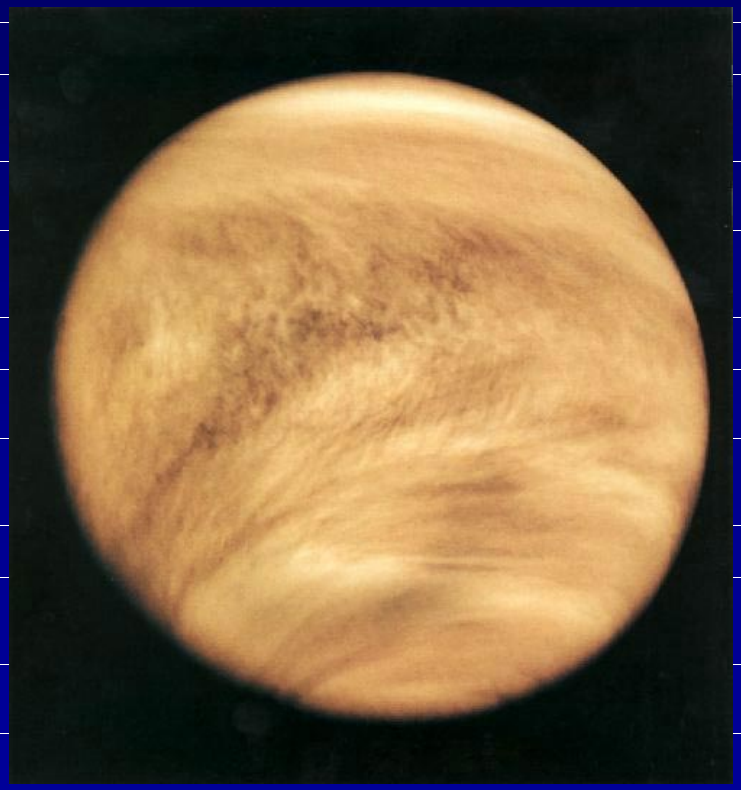
- Introduction
- “Dragon” VE application
- Usability evaluation methodologies
- Application of methodologies
- Results
- Conclusions

User-Centered Design & Evaluation

- **Virtual Environments: from *Mars***



- **Usability Engineering: from *Venus***



User-Centered Design & Evaluation

- **Purpose of our research (basic):**
  - **Design a *usable* VE interface**
  - ***Evaluate* and *iteratively improve* VE user interface design**

- **Purpose of our research (meta-level):**
  - **Identify *general principles* and *most important parameters* of VE user interface design**
  - **Identify *effective techniques* for VE usability engineering**

“Dragon” VE System

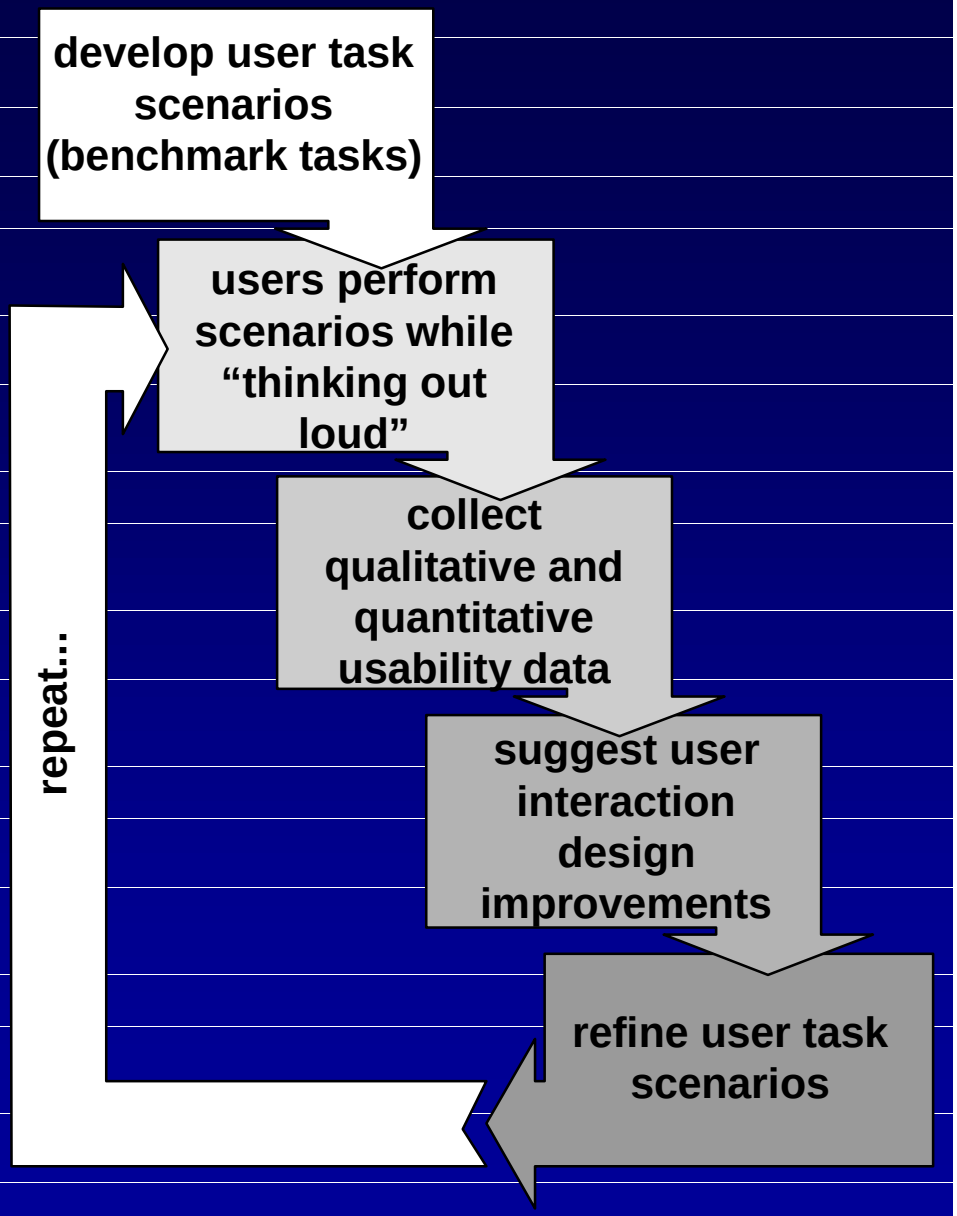
- VE for battlefield visualization
- Implemented on a Responsive Workbench
- Numerous iterations of UI design

Usability Engineering Methodologies

Expert Heuristic Evaluation:
assessment by UI design experts, to determine violated usability design guidelines

Formative Evaluation:
assessment with users, to iteratively determine and improve usability

Summative Evaluation:
assessment with users, to determine which among several design alternatives is "best"



Formative Evaluation

Use of Methodologies

- Preliminary observational studies revealed *generic tasks*:
  - navigation
  - object manipulation
  - object selection
  - object querying
  - query response
  - object aggregation

- Focus on *navigation*
  - fundamental to all other generic tasks

Approach

- Dragon VE was instrumentable testbed for *heuristic* and *formative* work
- Developed scenarios of benchmark user tasks
- Extensive evaluations performed over nine-month period
- One to three users per evaluation cycle
- Based on results, iterate design
- Four major cycles of evaluation

Expert Heuristic Evaluation

- Experts assessed UI design
- Initially "free play", then structured scenarios
- One or two other experts observing
- Guided by *framework of usability characteristics of VEs* [Gabbard & Hix 1999]
- Discovered and addressed usability problems:
  - *Poor mapping* of navigation tasks to flightstick buttons
  - *Missing functionality*
  - *Damping* of map movement in response to flightstick movement
  - Graphical and textual *feedback*

Formative Evaluations

- Six sessions; formal protocol; single user per session
- User first asked to use flightstick
- User then asked to perform scenarios
  - Time ranged from 20 minutes to more than one hour
  - Timed individual tasks; counted errors
  - Noted critical incidents
- Two evaluators (observers) in each session
- Four major iterations of Dragon UI design over one year

First Iteration Results: Virtual Sandtable

Based on real-world *sandtable metaphor*: exo-centric map manipulation

Utilized 5 DOF (x, y, z, h, p)

- + Mapping of buttons to navigation tasks worked well
- – Users wanted terrain-following capability, to “fly” over map
- – Basic metaphor cumbersome

Second Iteration Results: Point & Go

Based on real-world *airplane metaphor*: ego-centric flying

One gesture moves anywhere on map

Utilized 6 DOF (x, y, z, h, p, r)

+ Attempted to avoid navigation modes
– Single gesture to move around was not powerful enough to support diverse navigation tasks
– Users wanted exo-centric rotate capability

Discovered *control* vs. *convenience* trade-off

Third Iteration Results: Modal

- Based on combination of *flying* and *sandtable* metaphors
- Each navigation task was *separate mode*
- Utilized 5 DOF (x, y, z, h, p)
  - Users found it cumbersome
  - Too much control, not enough convenience

Fourth Iteration Results: Integrated Navigation

Based on combination of *flying* and *sandtable* metaphors

Combined modes mapped to flightstick buttons:

1) Pan & zoom (x, y, z)
2) Pitch & heading (h, p)
3) Exo-centric rotate & zoom (y, h)

Fine-tuned damping and acceleration

+ Users found navigation to any location easy, and easy to switch among tasks
+ Achieved control vs. convenience compromise

Results: Significant Navigation Variables

- **Identified 27 key variables that effect VE navigation → narrowed to *5 variables***

User Tasks

1. navigation presets
2. user scenarios

Input Devices

3. *navigation metaphor*
4. navigation degrees-of-freedom
5. gestures to trigger actions
6. speech input
7. number of flightstick buttons
8. input device type
9. movement deadspace
10. movement damping
11. user gesture work volume
12. *gesture mapping*
13. button mapping
14. *head tracking*

Virtual Model

15. mode switching
16. mode feedback
17. number of modes
18. visual navigation aids
19. dataset characteristics
20. visual terrain representation
21. visual battlefield object representation
22. visual input device representation
23. size of battlefield objects
24. visual object relationship representation
25. map constrained vs. floating

Presentation Devices

26. *visual presentation device*
27. *stereopsis*

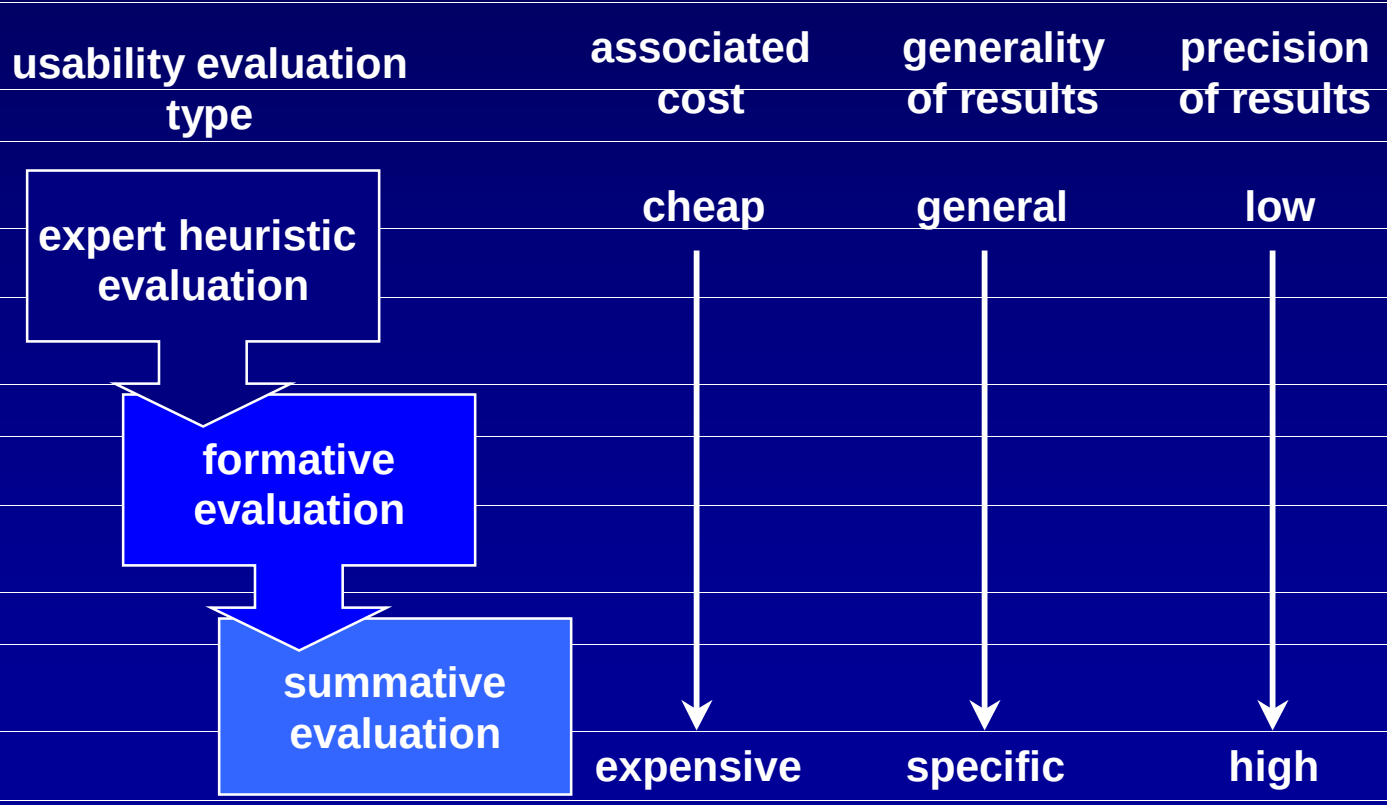
Ongoing Summative Studies

- ***Goal***: systematically examine five variables most likely to influence VE navigation
- ***Summative Evaluation***: assessment with users, to statistically compare user performance with different UI designs

Variable	Levels	
1) stereopsis	absent	present
2) visual presentation device	virtual workbench	desktop
3) gesture mapping	controls rate	controls position
4) navigation metaphor	egocentric	exocentric
5) head-tracking	absent	present

Conclusions

- **Successful, cost-effective progression from *heuristic* to *formative* to *summative* evaluations**



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