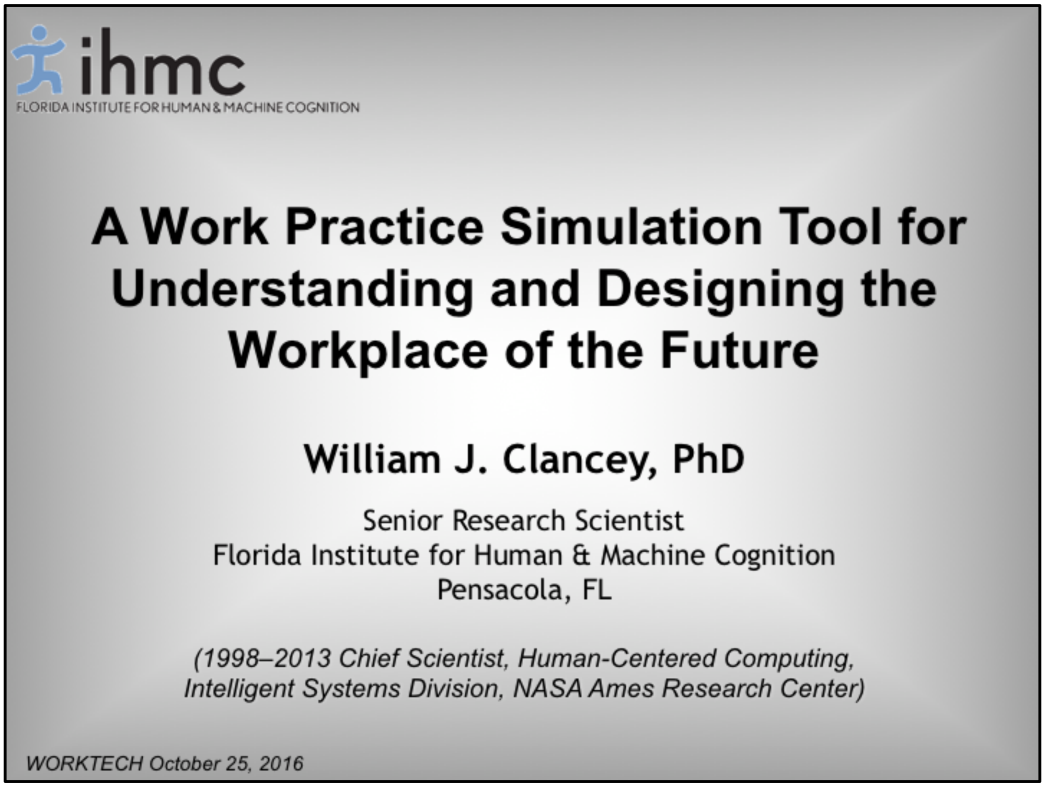
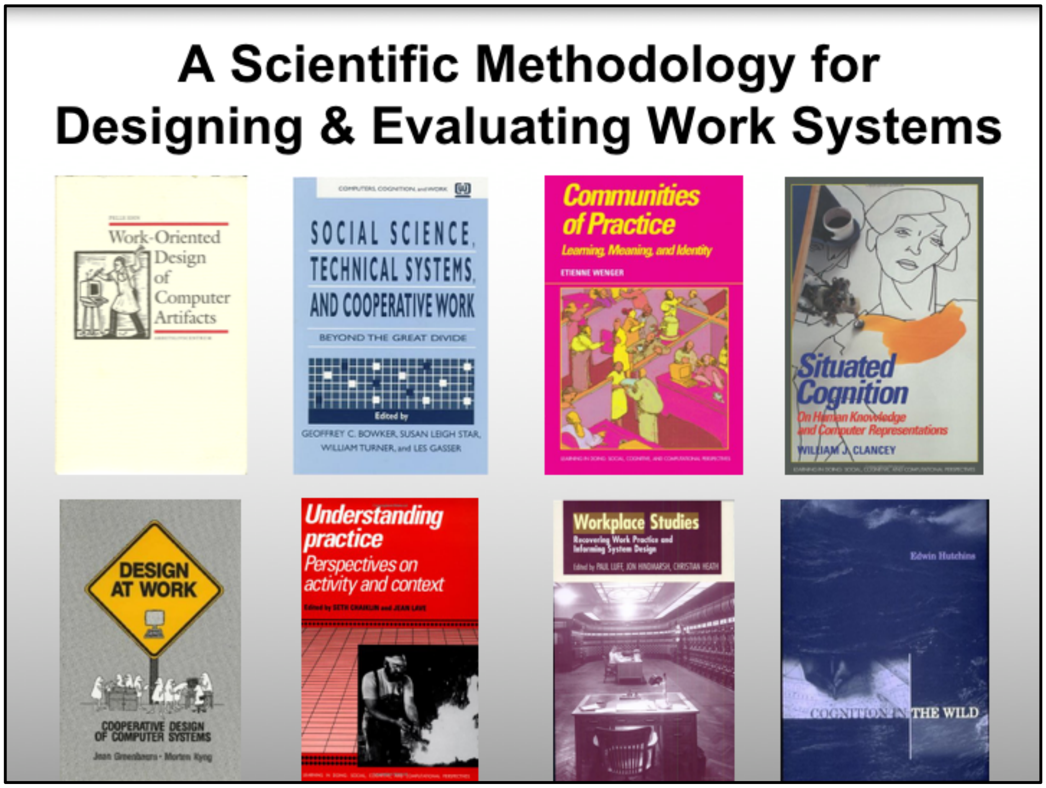


This was an invited keynote presentation at the WORKTECH 16 - West Coast Conference, San Francisco, CA.

The example project, OCAMS, was performed while I was on an IPA assignment at NASA Ames Research Center as Chief Scientist, Human-Centered Computing, Intelligent Systems Division.

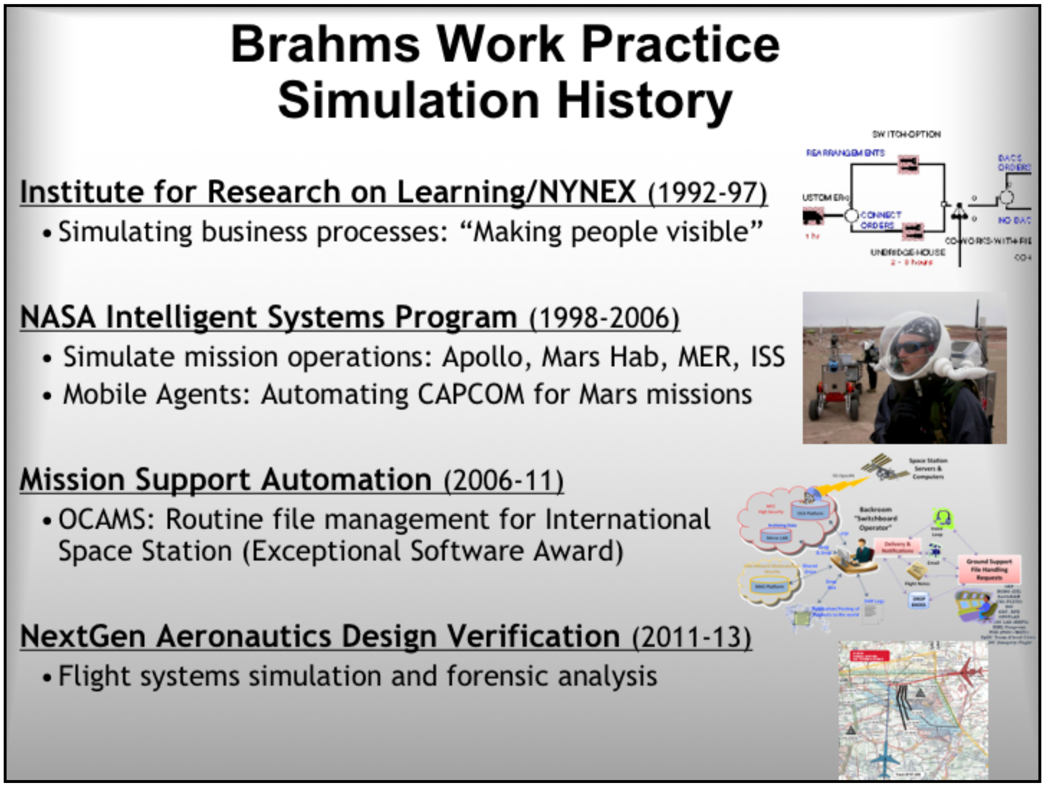
A key message is that designing the workplace of the future depends not just on making automation "smarter" — we must pay more attention to the skills, roles, and practices of the people in how they relate to each other and their tools. This is the "human-centered" approach to systems design.



Over the past 25 years a work systems design methodology has been formulated and used in workplaces throughout the world including many corporations.

The social perspective on work was pioneered in the 1980s by researchers from Scandinavia: Ehn, Bradley, Engeström. The research spread to the University of California in San Diego, Xerox-PARC, EURO-PARC, IBM, the Open University in the UK, and many other places.

We start by studying work practices so we can understand the problem we are trying to solve and how a solution will affect the existing roles & responsibilities, activities, tools, layout, work schedule, work flow, etc.



Brahms is a multiagent work systems design tool for modeling and simulating activities, used extensively to design aerospace work systems. The Mobile Agnets Project used Brahms for designing and implementing agents running on multiple computers; agents communicated over the internet using a service-oriented architecture. The Mobile Agents Architecture (MAA) is thus an agent-based systems integration framework allows interoperabiity of arbitrary hardware and software components by effectively converting them into Brahms agents.

Key aspects of the Brahms modeling framework:

- Model activities—conditional interactive routines
- Model perception & inference ascontextual with respect to activities
- Activities subsume subactivities, more specific conceptions of “what I am doing now”

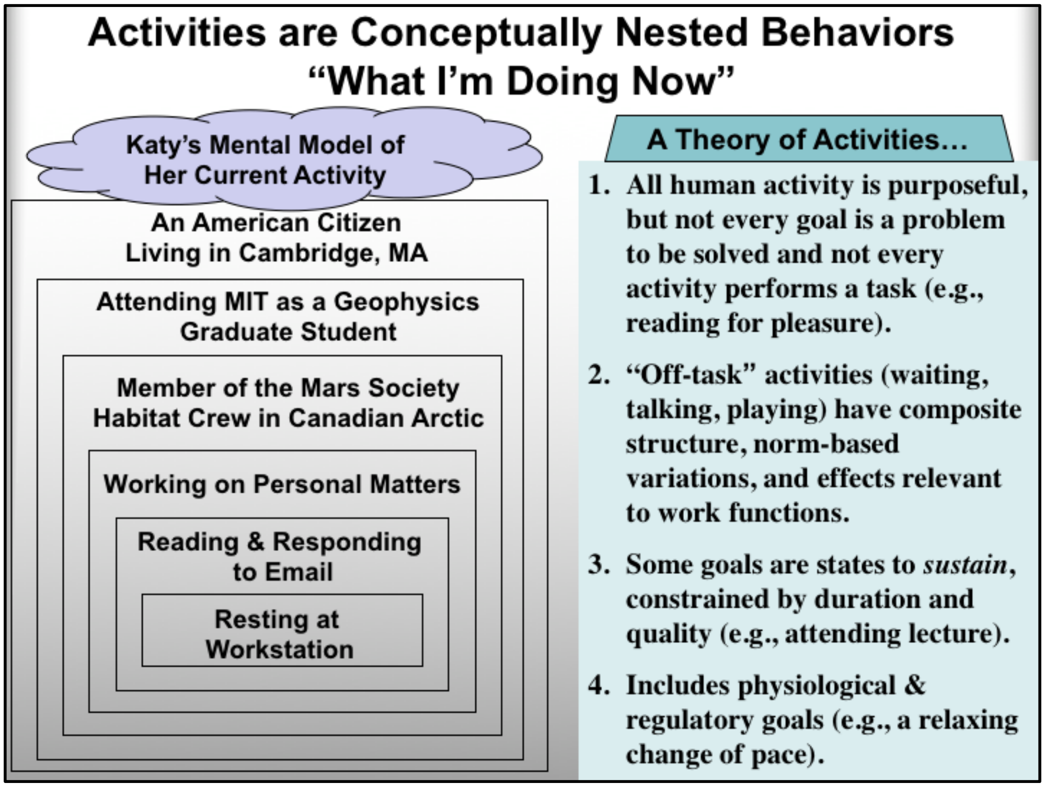
70+ FTE worked on Brahms at NYNEX, IRL, and NASA from 1992-2013 until it was commercialized under an exclusive license by Ejenta. More than $10 million was invested by NASA (1998 – 2013) through the Intelligent Systems Program (to develop and apply the MAA), OCAMS (which automated routine file management with the computers onboard the ISS), and Brahms-GÜM (a general model of pilot interactions with air traffic controllers and the aircraft’s automated systems, particularly TCAS). This presentation focuses on the systems architecture and methods used for developing OCAMS.

In the next few slides I present the theoretical background which is the basis for the Brahms modeling framework.

People conceive their everyday affairs (their practices) as social actors in activities, in which they perceive, infer, move, manipulate objects, and communicate in some physical setting (e.g., going to the grocery to buy dinner). Activity motives and modalities vary widely (e.g., waiting in line, listening to music, sleeping), all of which require time and occur in particular settings.

Brahms is a tool for simulating activities, i.e., chronological behaviors including perception, reasoning, communicating, manipulating, moving. Notice that waiting is an activity, as is sleeping. We model what a person is doing during their life, not just their assigned work tasks. Not all actvities have a well-defined goal (e.g., field science exploring); the purpose may be for pleasure of different kinds (e.g., watching movies, dancing), or just to bide the time (e.g., listening to the radio while driving).

For more information, see Clancey, W.J. (2002) **Simulating activities: Relating motives, deliberation, and attentive coordination**, *Cognitive Systems Research* 3(3) 471-499, September, special issue on situated and embodied cognition.

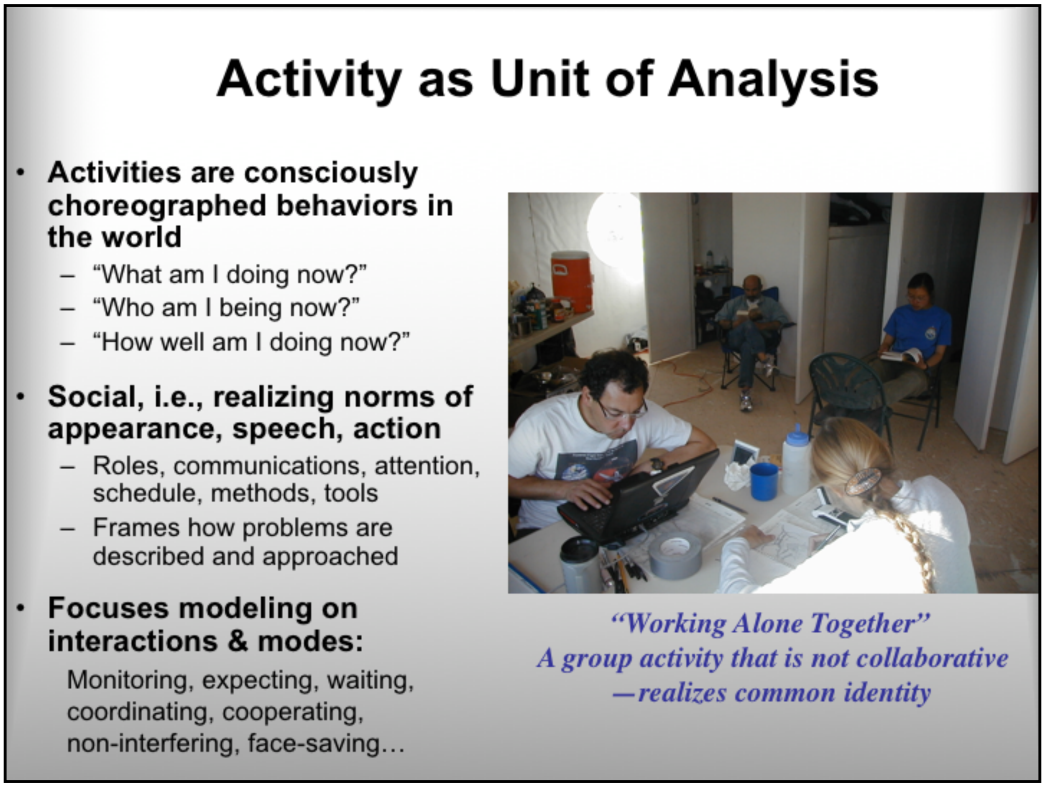


Activities are simulated in Brahms using the subsumption architecture.

Functions and procedures in a computer program, as well as tasks described by cognitive task analysis, invoke finer-grained processes, such that the "callling" procedure or task is suspended while a sub-procedure or sub-task is "executed." By contrast, a person engages in general and more specific activities simultaneously. This architecture was introduced by Rod Brooks in the 1980s as a means of implementing layers of perceptual-motor coordination in a robotic system.

As an example of subsumption of activities in people, consider Katy (prior slide bottom left) in the activity of resting. She conceptually remains in the activity of working at her computer; she didn't choose to rest in her room, leaving the workstation area-- she is "just resting for a moment" as a modality, a way of remaining engaged in the workstation computer activity,. Furthermore, while doing this, she is also engaged in the activity of being a member of the FMARS simulation, in the activity of being a business trip (not a vacation) within her university role, etc. Vladimir shares many of these activities, though he is also "a foreigner traveling in the US who works for ESA."

How an activity is performed is affected by the context of conceptually broader activities, specifically through what we call "behavior norms" – aka "practices."



For a person, "the situation" is simultaneously perceptual, physically Interactive (including resting with your head on the table), and conceptual.

In adopting "Activity" as analytic perspective, we examine for each actor:

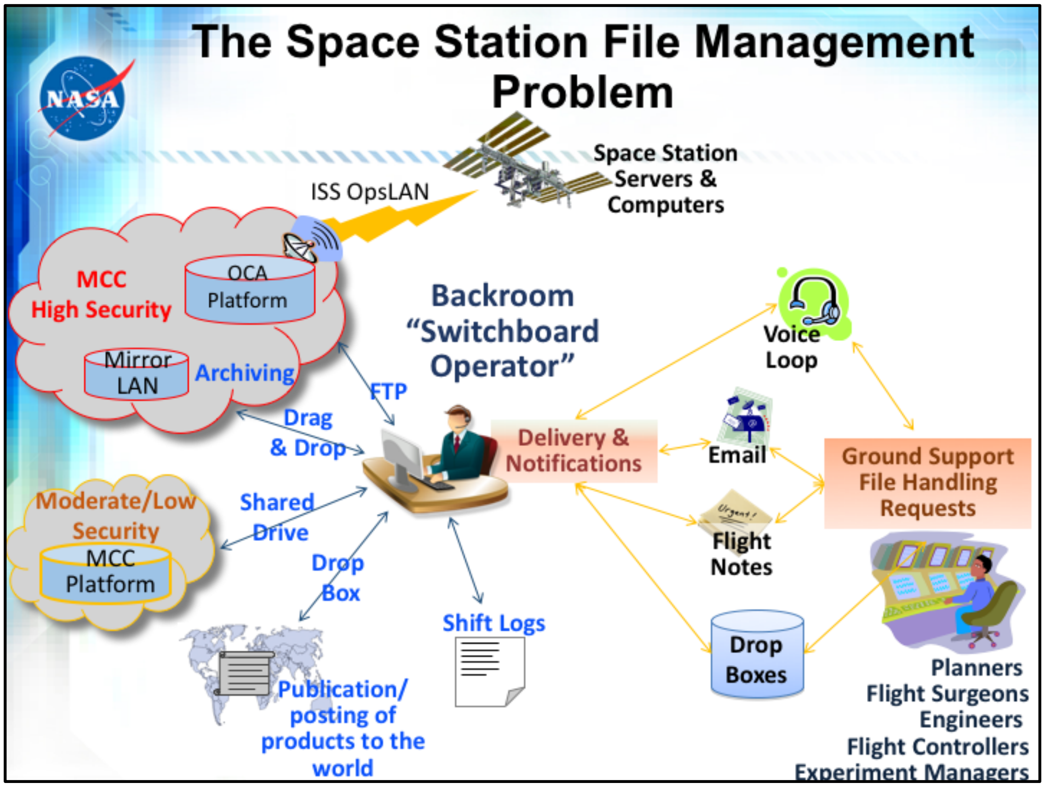
- What is seen and heard
- What is manipulated/moved (either directly by manual control or indirectly by remote command/instruction)
- What is conceived

These behaviors are conceptually choreographed in an ongoing, usually tacit understanding of "what I'm doing now," encapsulating:

→ *roles ("who I'm being now"),*
→ *norms ("what I should be doing"; "how I should be dressed/talking/sitting"), and*
→ *progress appraisals ("how well I'm doing").*

→ "Context" for a person is conceptual-Interactive --- not just the physical environment or what is "input" by an experimenter.

For more information, see Clancey, W.J. (2002) **Simulating activities: Relating motives, deliberation, and attentive coordination**, *Cognitive Systems Research* 3(3) 471-499, September, special issue on situated and embodied cognition.

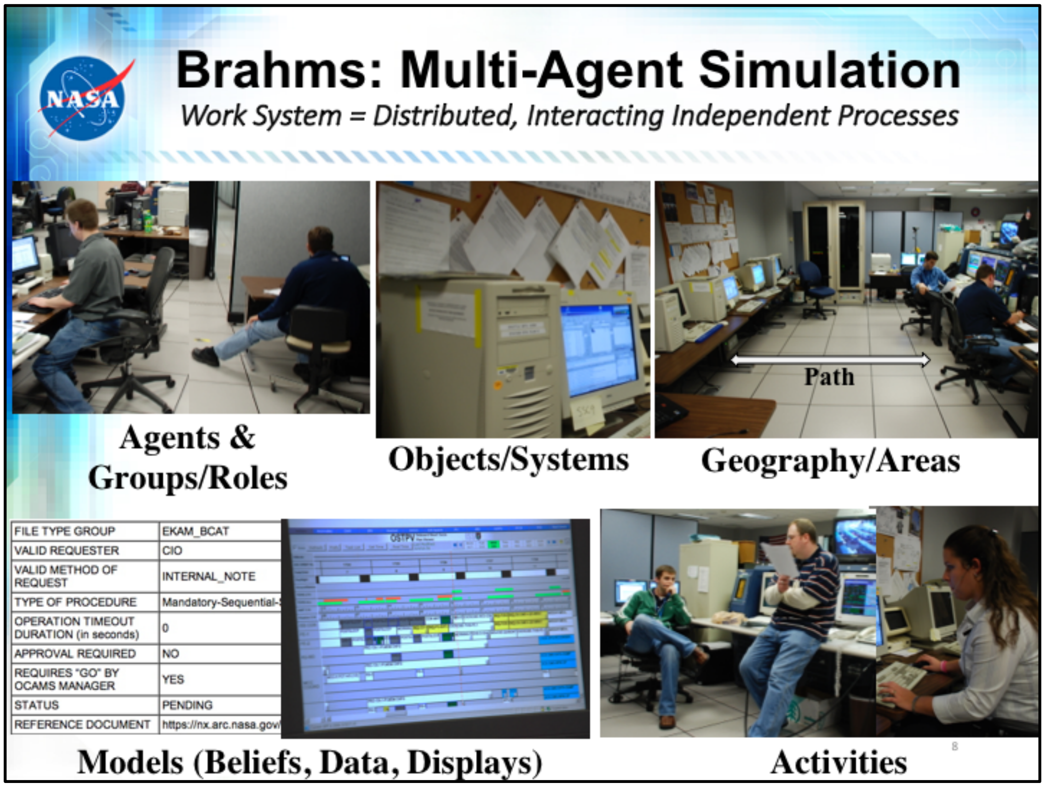


Brahms was used to develop a collection of "agent" program called OCAMS, which received the Johnson Space Center Exceptional Software Award, the first awarded to researchers at another NASA center. The problem was to remotely mange the file system onboard the ISS computers.

OCA = Orbital Communications Adapter – refers to a PC card in the computer used to transfer files from JSC backroom through Deep Space Network (TDRS satellites) to ISS computers. The OCA Officer was a backroom starter position; an aerospace engineer served as the "switchboard operator" between ISS and ground support.

In developing Mobile Agents for Mars explorers, we started with the idea that CapCom on Earth was not immediately available so we sought to automate on Mars what Capcom on Earth was doing for the astronauts. In the OCAMS system it's turned around. We start by looking at the ground support and see how to make it more efficient. We have automated the routine work of the OCA Officer, a kind of switchboard operator who supports Capcom and all of ground support by managing files onboard the ISS. The result is eliminating that 24/7 position and a savings of millions over the next decade.

OCAMS was developed incrementally over 4 years by automating aspects of file management: Mirroring & Archiving; Uplink & Downlink; Delivery & Notification; Procedure Execution.

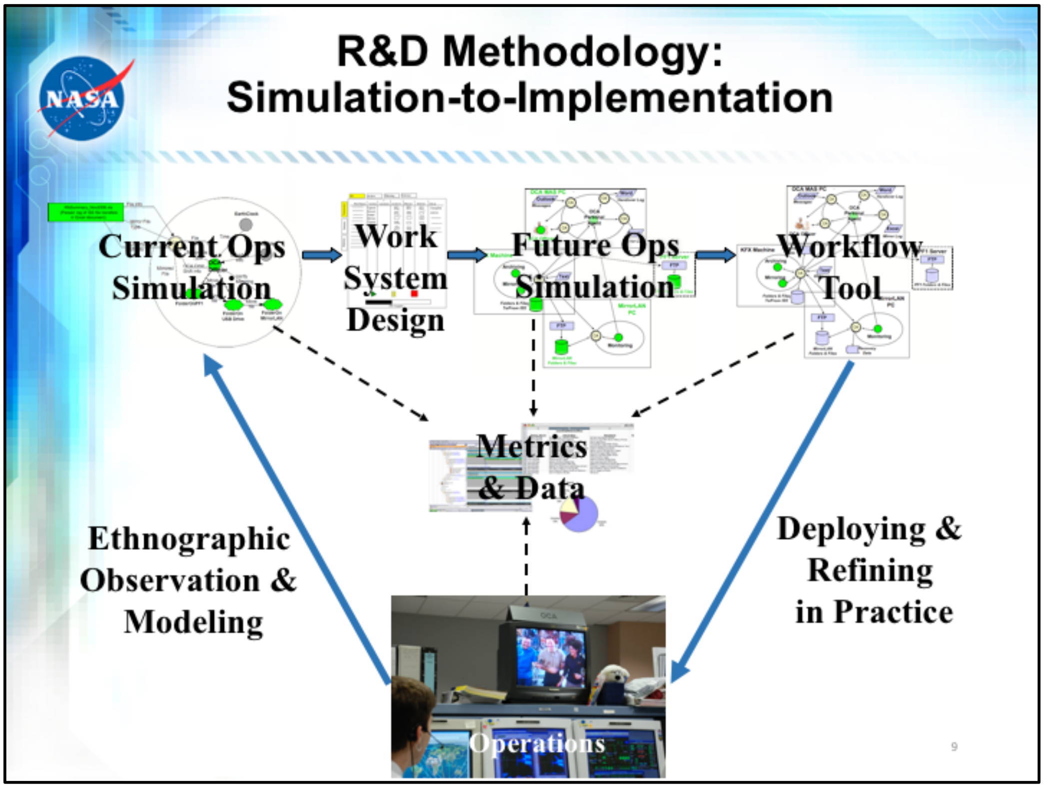


Notice again how Brahms models are different from task or functional models that describe what is supposed to occur; in modeling activities we are describing behaviors, what people do, where and how—their practices. Activities in Brahms model how perception, movement, communication, and inference occur over time contextually. The status model of every agent and object updates every 1-3 seconds.

This slide shows the main components of a Brahms model with examples from the ethnographic study of the OCA Officer's work practices. The bottom right shows the activity of a shift handover with the incoming hOCA officer sitting and the incoming OCA officer standing; an officer at a related position in this backroom of Mission Control has joined to discuss the ongoing work and open issues.

In the OCAMS model all of the OCA officers are "clones"—individual agents inherit their behaviors from a model the OCA Officer Group. However, individuals have their own beliefs about their work schedule and ongoing responsibiities during the shift. Hence each agent has his or her own model of the world.

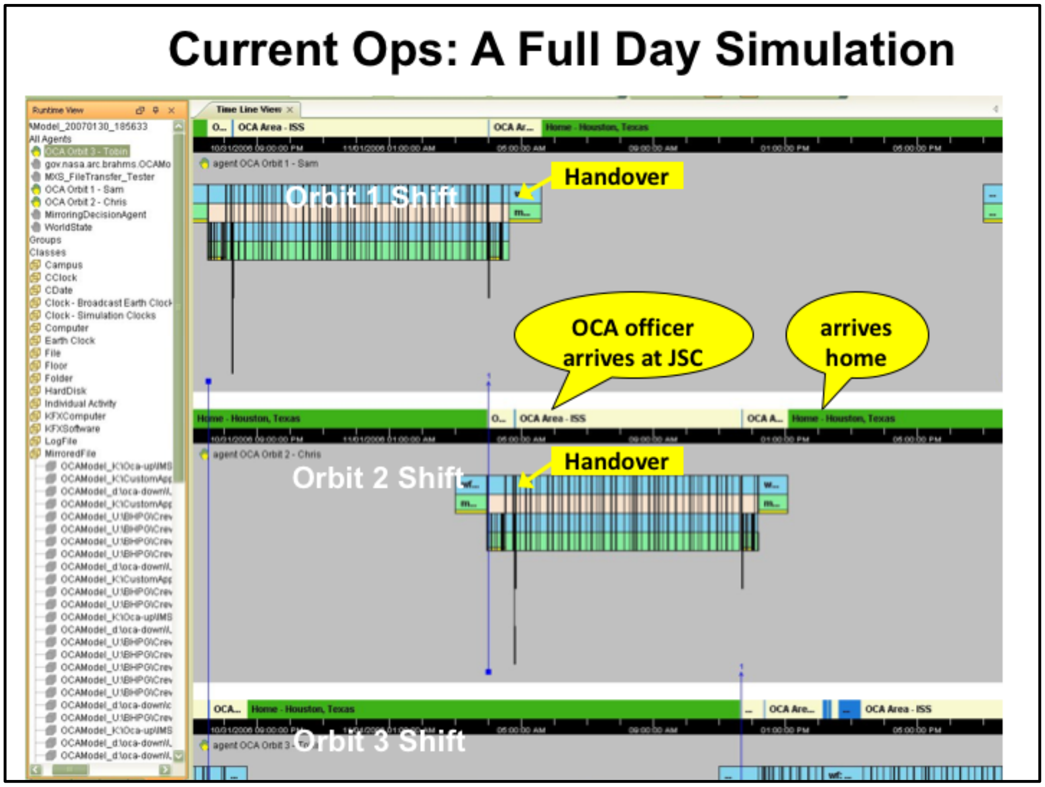
The "geography" path shows how the OCA officer moves his/her seat to transfer files to a local LAN (the "mirroring activity"). Objects include furniture as well as computer systems and telephones with which people interact by receiving and conveying information. Data on displays are represented as text in the Brahms model.



The *Simulation to Implementation* software development approach involves modeling and simulating current practices, developing a new work system design, and simulating that as the "future operations." This simulation is created from the Current Ops model by"cutting" part of the OCA officer model and "pasting" it into a new agent, a software program called OCAMS. Hence OCAMS automates some of the work previously done by the OCA Officer. In this new design the OCA Officer has a new activitiy of interacting with the OCAMS tool, whose interface is also modeled in the Brahms simulation. *Simulation to Implementation* is an example of how the method of design thinking can be combined with more traditional approaches in the field of engineering -- observation, modeling, verification, automation.

Using a Brahms activity-based modeling simulation for design how the framework enables capturing, augmenting, and adapting successful practices to create a new, more efficient and productive work system. Now the OCA Officer is freed to spend more time on difficult matters, handling other job responsibiltites, and providing more customized one-off service to ground support personnel. Eventually the OCA role was combined with another backroom position.

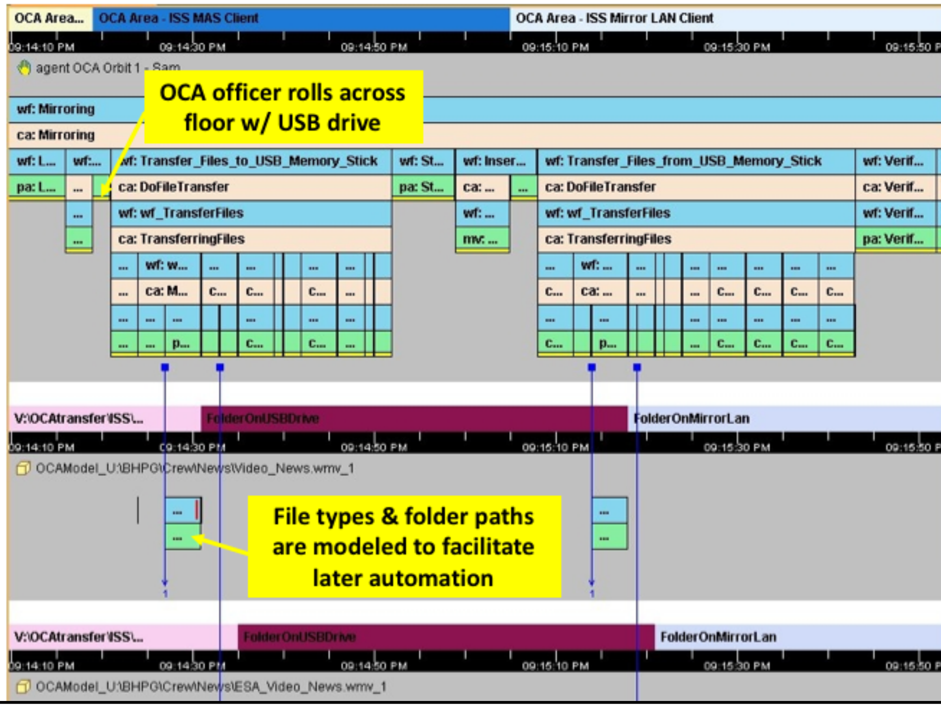
See references on page 13 for more information.



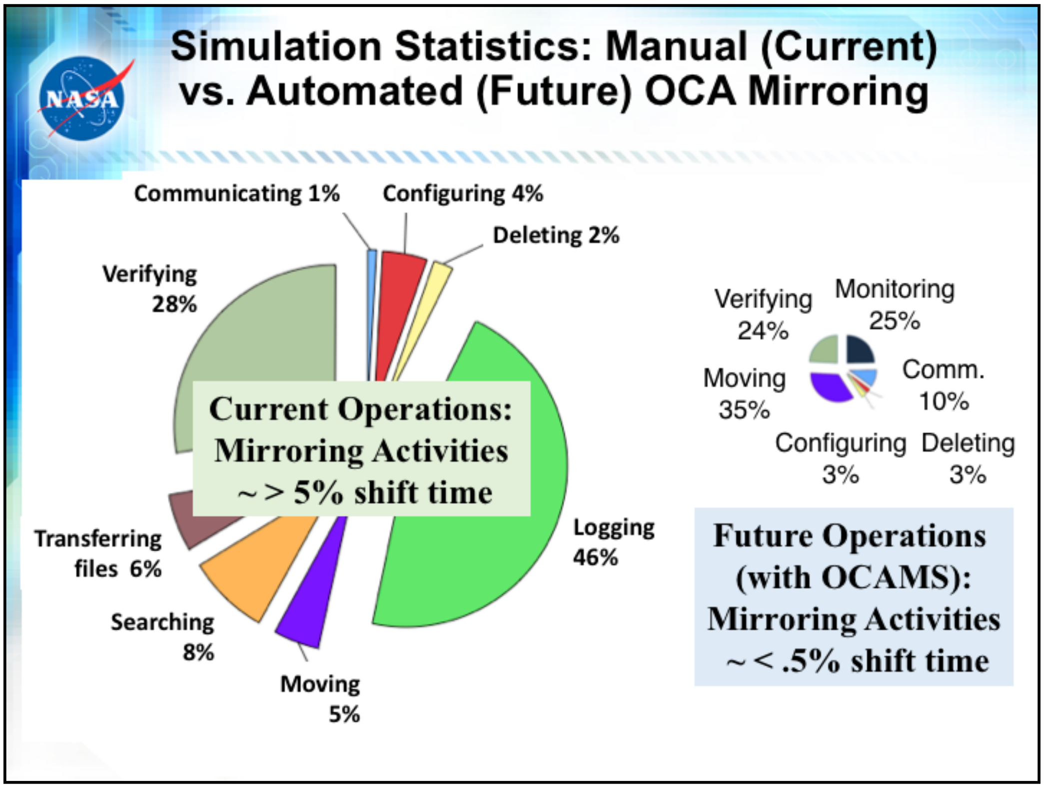
Brahms simulations can be viewed using the Agent Viewer tool.

Here three shifts are shown (nearly 24 hours simulated time), with all of the activities visually compresssed. We can select particular simulated people, tools, etc. and view how they interact in selected periods of time. The lines between shifts represent communications between outgoing and incoming OCA Officers during the Shift Handover activity.

Current Ops: Mirroring Activity

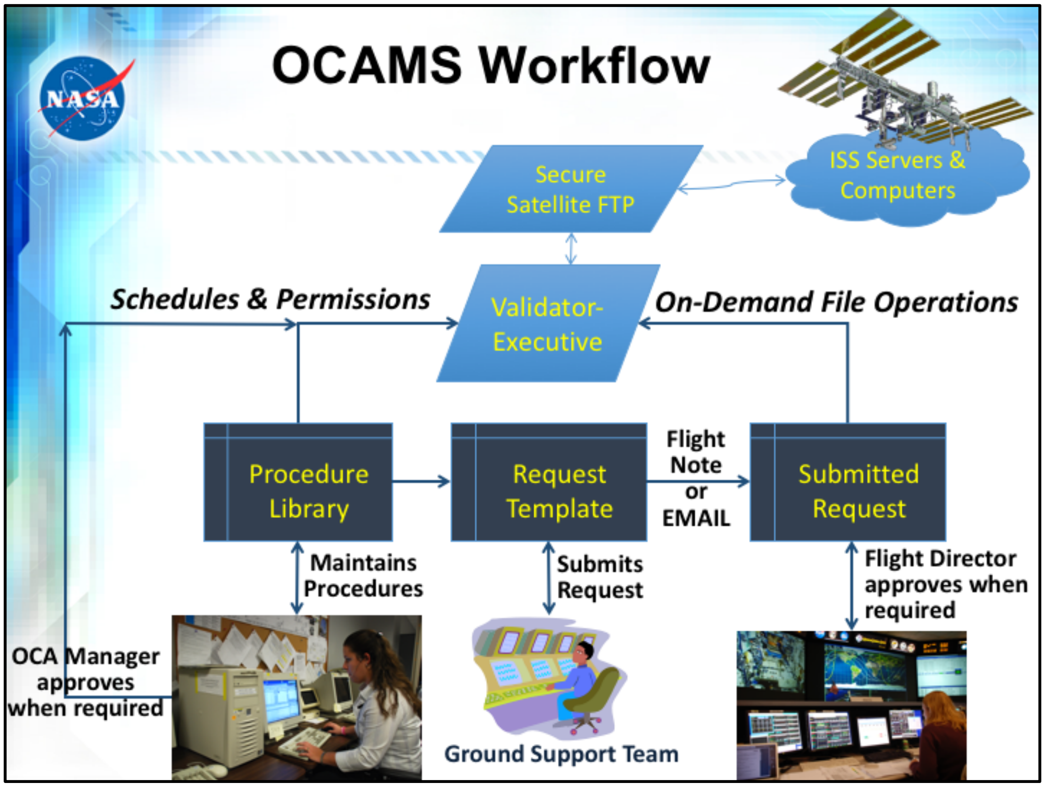


Using the Brahms Agent Viewer, we have drilled down for details about activities (beige “composite activities” and green “primitive activities”) and their conditional relations (blue “workframes”)



The Brahms simulation can be instrumented to collect statistics about the duration of activities.

Comparison of the current operations to the future work simulation -- using a software agent, OCAMS, to automate the work -- predicts that the total time required during the shift devoted to the “mirroring” activity (copying files to a local area network) will be reduced by 90%.



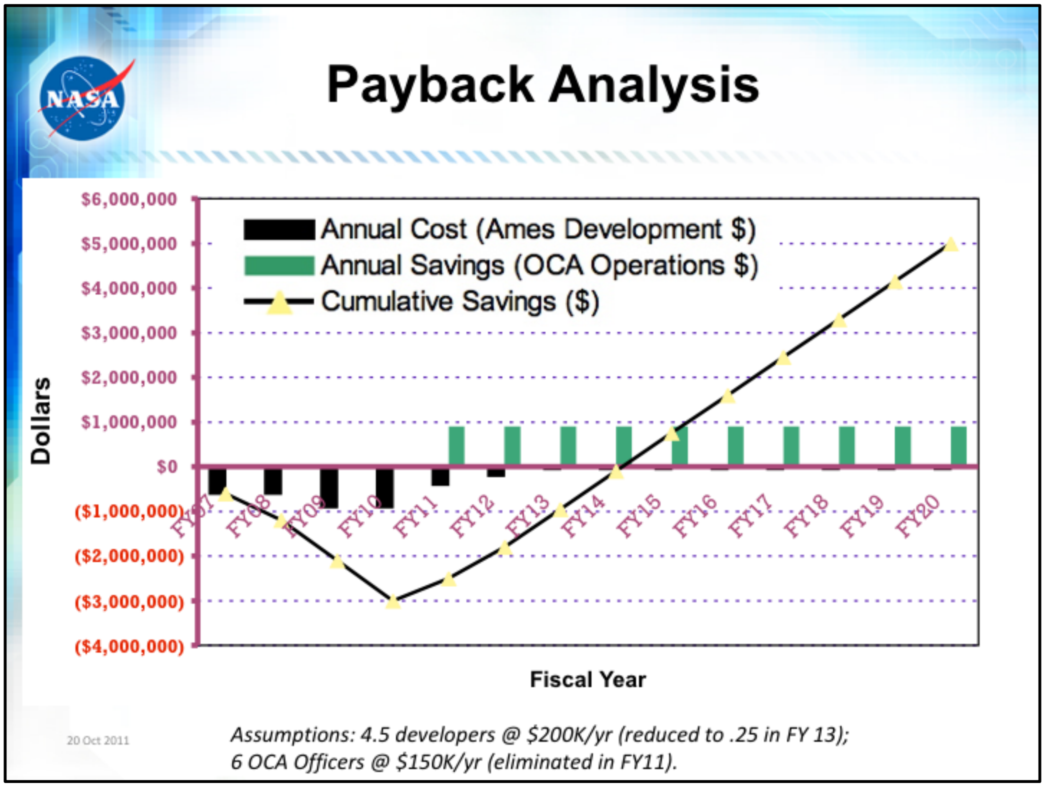
This diagram shows the workflow using the OCAMS tool. Specifically, it shows the flow of documents that form the backbone of OCAMS' operation.

The procedures that specify OCAMS operations must be comprehensible to people so they can be created, verified, revised. Plus these procedures must provide all of the information that OCAMS requires to carry out the desired operations, including validating on-demand requests and finding the appropriate files.

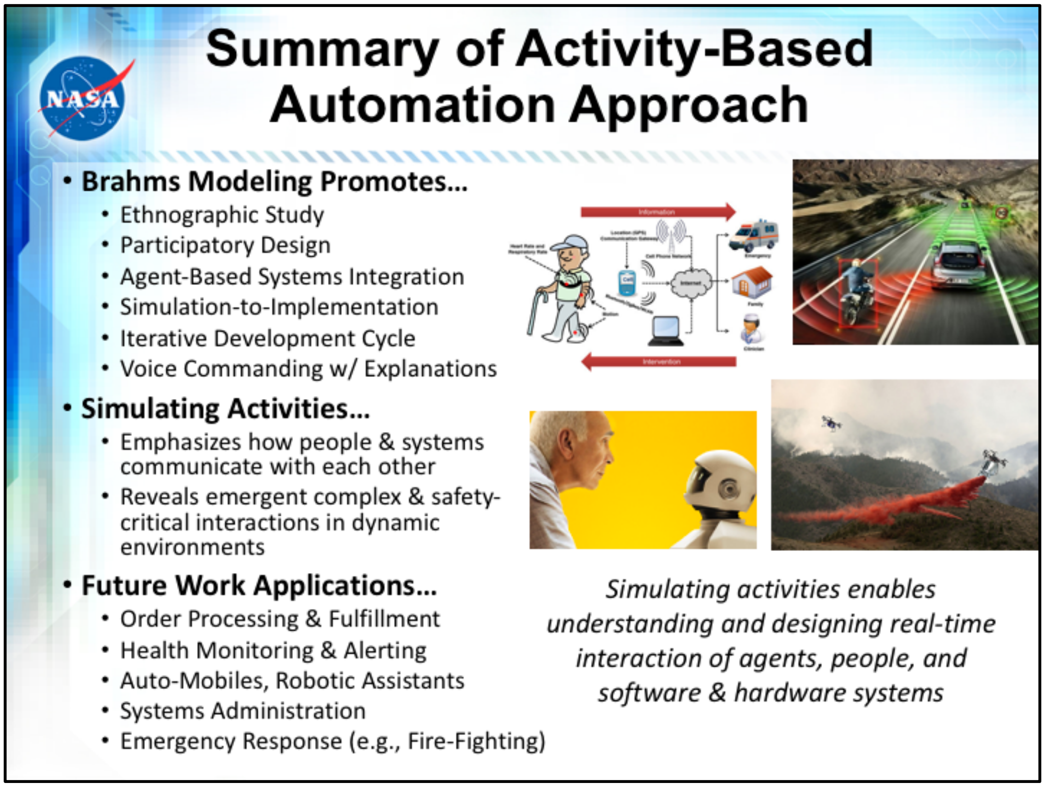
For more information about OCAMS, see –

Hall, T., Clancey, W.J., Sierhuis, M., Hood, D., Tucker, T., Buckley, C. (2009) **Automating ISS file management using agent-based systems integration**. In H. Lane & K. Lulla (Eds.), *Biennial Research and Technology Research Report*. Johnson Space Center, TM-2009-214795, pp. 184-185.

Clancey, W.J., Sierhuis, M., Seah, C., Buckley, C., Reynolds, F., Hall, T., Scott, M. (2008) **Multi-agent simulation to implementation: A practical engineering methodology for designing space flight operations**. In A. Artikis, G. O'Hare, K. Stathis, & G. Vouros (Eds.), *Engineering Societies in the Agents' World VIII.* Athens, Greece, October 2007. Lecture Notes in Computer Science Series, Volume 4870. Heidelberg Germany: Springer, pp. 108-123.



OCAMS allowed eliminating a backroom position at NASA Johnson Space Center, thus lowering the cost of ISS operations. Since 2014 OCAMS costs have been recouped and real savings accumulate. This diagram is based on 2007 dollars.



This slide relates to the WorkTech conference theme of addressing implications for ”future work systems.”

The main idea is that activity-based simulation is useful for designing work systems involving automation such as self-driving cars, robots, wearable medical devices, and drones. The inset image is from the 2012 film ”Robot & Frank.”

During 1992–2013 at IRL/NYNEX and NASA we developed a mature methodology for creating Brahms models using the methods listed here.

Most of the systems starting in 2002 were voice-commanded, using technology related to what became SIRI. The MAA framework allowed integrating arbitrary hardware and software. For examples, watch the videos posted as “WJClancey” on YouTube.


Grateful thanks to my colleagues…
Gitti Jordan
social anthropologist
Pat Sachs
cognitive anthropologist
Maarten Sierhuis
computer scientist
Mike Shafto
psychologist
Charlotte Linde
social linguist
Chin Seah
Ron von Hoof
software engineers

For more information…

Mobile Agents: *Automating CapCom Using Mobile Agents and Robotic Assistants. NASA Technical Publication, 2007.*

- Roles for agent assistants in field science: Personal projects and collaboration
- Automating ISS file management using agent-based systems integration
- YouTube: "Clancey Power Agents" & "Clancey DesertRATS"

Brahms-GÜM: *Work Practice Simulation of Complex Human-Automation Systems, NASA Technical Publication, 2013.*

- Brahms: Simulating practice for work systems design
- Simulating activities: Relating motives, deliberation, and attentive coordination

→ All publications available: http://Bill.Clancey.name

For recreational reading – related ideas applied to the scientists' experience exploring Mars through a robotic laboratory

Contact – wclancey@ihmc.us