Agent-Supported Mission Operations Teamwork

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NASA Human Centered Computing
Task-level Review

University of Central Florida

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Team Members

- Analysis and design methods
  - Carroll Thronesbery, Kathy Johnson, David Overland, Grace Hua
- System management agents and testbed
  - Debra Schreckenghost, Land Fleming and Luis Flores
- Information assistant agents and team tools
  - Arthur Molin, Kenneth Jenks, Kevin Kusy, Dan Smith
- Team tools and mission spin-offs
  - Patrick Oliver, David Overland, Gene Peter and Kevin Taylor (DV) and Kathy Johnson (SD – SMART project for SURGEON/BME)

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Goals for Users

- Make automation by agents easy to use, supervise and direct
  - Smooth transitions into close supervision and intervention
- Manage information and communication to decrease distraction, interruptions, workload and errors
  - Smooth handovers across groups and shifts
- Reduce mission impact of off-nominal situations
- Increase morale and decrease turnover

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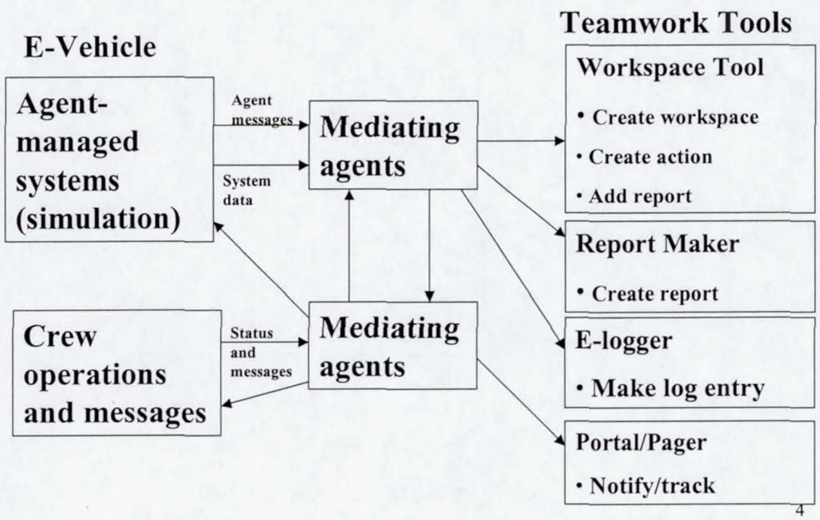
Agents and Team Tools



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Accomplishments

1. Collaborative agents - mixed initiative and creation of instructions for mediating agent
2. Methods for prototyping, evaluating and evolving socio-technical systems
3. Technology infusion: teamwork tools in missions
4. Demonstrations in simulation testbed

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1. Agents that are Team Players

- System management agents: Mixed initiative interaction
- Mediating assistants: Easy to manage

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Mixed Initiative Interaction

- Either user or agent can steer the interaction
- First step toward automation that works with the user
  - Balances both user needs and its own goals in deciding to act
  - Determines whether conditions support user-requested action
- Demonstrated: interaction to "fill out" and execute incomplete command
  - User: Execute the N_2 leak test.
  - ISMA: Now, or plan in the future?
  - User: Now
  - ISMA: OGS is shutdown and the N_2 leak test can be performed now. Should I start the test? [or, Please wait for OGS steady state]
  - User: Yes [or, No or Abort - stop interaction]
  - ISMA starts test when gets the OK. [or, ISMA aborts if test conditions change or higher priority action is needed]

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Mediating Assistants

- Information manager: Intelligent Briefing and Response Assistant
  - IBRA Engine watches data stream for triggers and executes Act-Whenever actions
  - User-defined actions can be added for a particular domain
- Users specify how IBRA should handle events with Briefing and Response Instructions
  - Triggers: Patterns to recognize when event of interest has occurred
  - Actions: What IBRA should do when event occurs
    - Collect additional data, create log entries, make reports
    - Notify appropriate people that event has occurred

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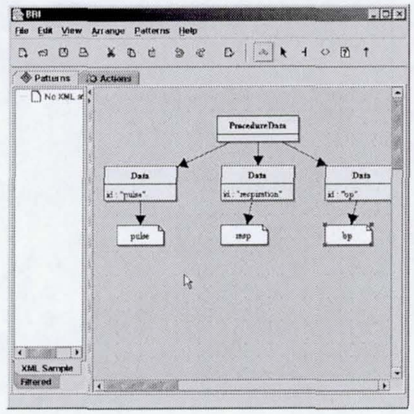
Briefing and Response Instruction (BRI) Editor

- Simple for discipline specialist to create a BRI
- Create trigger based on:
  - Previous data logs
  - Data declaration files
  - Existing BRIs
- Choose actions from palette
- Trigger and action structures can be simple or complex



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Example: Specifying Leak Test Instructions

- Set of BRIs that are activated together
  - BRIs can activate and deactivate other BRIs
  - May be loaded into a special-purpose IBRA
- Measure time to reach threshold values
- Reporting with triggered alternatives
  - If the rate of change of pressure in the tank is too high, report leak
  - If the rate of change is nominal, report no leak

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N2 Leak Test

- N2 Tank has been observed to refill several times in a 24 hour period
- Suspicion—the tank is leaking
- Test—refill tank and monitor loss of pressure
- Log rate of loss and time to reach milestone pressures

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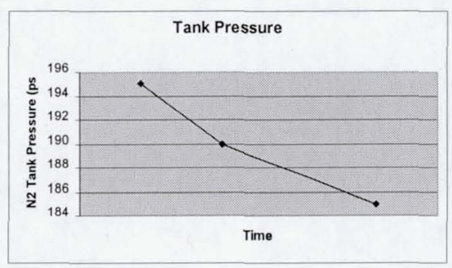
N2 Leak Test Procedure

- Note time and tank pressure at start of test
- Note time when pressure reaches 190 psi. Calculate and record rate of loss.
- Note time when pressure reaches 185 psi. Calculate and record rate of loss. End of test.



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IBRA to track procedure

- One BRI for each data point
- BRI structure
  - Trigger: when pressure reaches designated point
  - Actions:
    - Calculate rate of change from previous pressure/time measurement (except the first BRI)
    - Record information as log entry in logger
    - Save pressure/time information for next calculation (except the last BRI)

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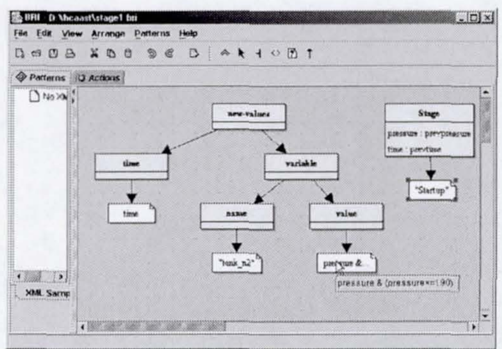
Review existing IBRA

- View BRI in BRI Editor
- Decide to add another data point, at 187 PSI, for additional precision
- Create new BRI based on existing one



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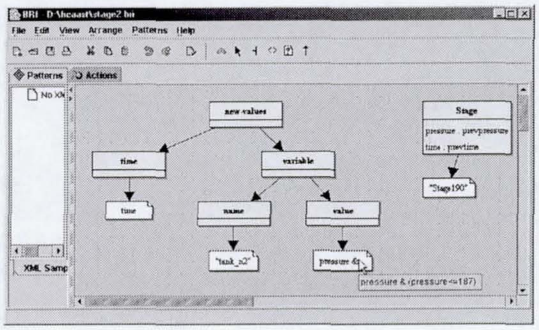
Create New BRI

- View new BRI
- Load BRI into IBRA
- Start IBRA
- Perform procedure



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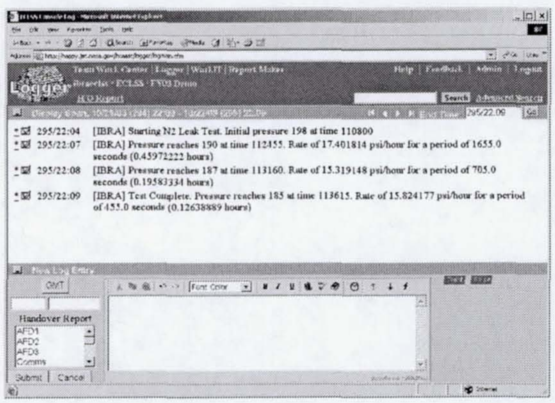
Review log at end of procedure

- Final report from the IBRA agent in the Logger
- Report saved for later reference
- Used as decision support



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BRI Editor Advantages

- Users can create additional IBRA capabilities without involving software developers
  - Adjust existing BRIs to fit changing needs
  - Add new ones (from scratch, copy and modify)
- Users can inspect existing existing BRIs to understand them better

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2. Human-Centered Methods

- Evolvable systems with "effortless specification"
- Requirements collection during prototyping

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Low Effort Specification

- Enabling evolution of sociotechnical systems
  - Users can customize software support
  - No need to go through formal software changes
  - Extends to unanticipated uses (as tasks change)
  - Extends to new groups of users
- Case
  - Logger: Snippets for common long text entries

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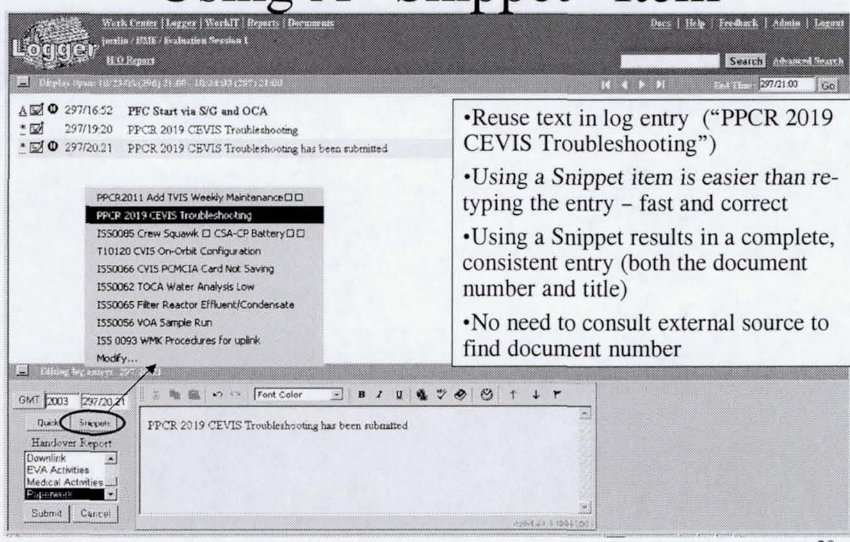
Using A "Snippet" Item



•Reuse text in log entry ("PPCR 2019 CEVIS Troubleshooting")

•Using a *Snippet item is easier than re-*typing the entry – fast and correct

•Using a Snippet results in a complete, consistent entry (both the document number and title)

•No need to consult external source to find document number

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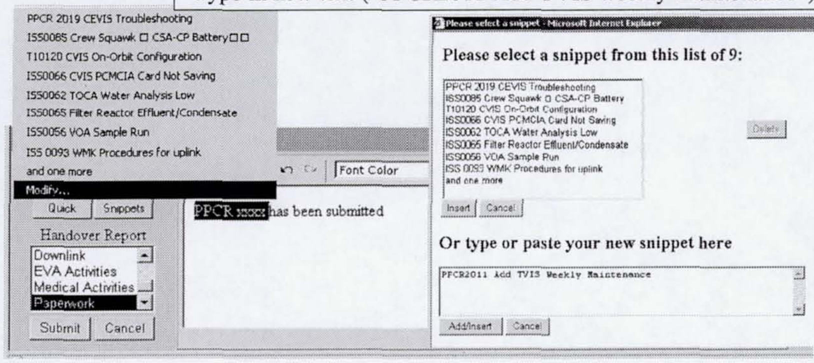
Adding A "Snippet" Item

•Highlight text to be replaced with Snippet string ("PPCR xxxx" from Quick menu entry, which attaches "paperwork" metadata)

•Click Snippet button

•Discover target text is not in list, decide to add it, select "Modify"

•Type in new text ("PPCR2011 Add TVIS weekly maintenance")



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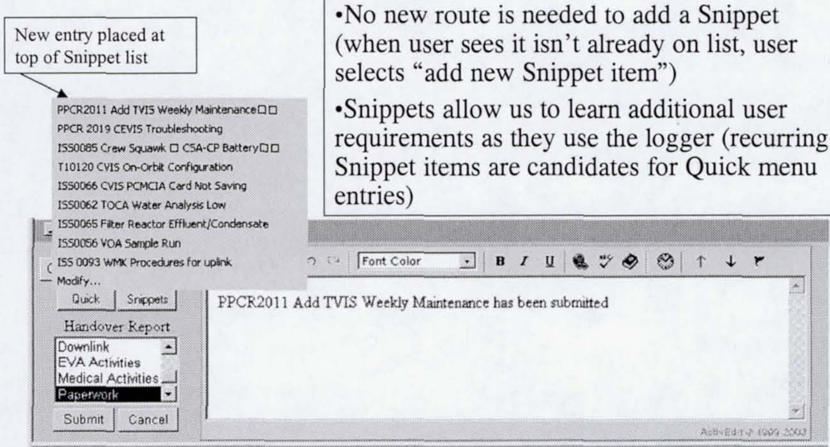
Adding A "Snippet" Item: Benefits

•Adding a new Snippet is no more work than typing in log entry

•No new route is needed to add a Snippet (when user sees it isn't already on list, user selects "add new Snippet item")

•Snippets allow us to learn additional user requirements as they use the logger (recurring Snippet items are candidates for Quick menu entries)



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Requirements from Prototyping

- Prototypes are developed to discover requirements
  - Inspection
    - Application itself is an inspectable artifact
  - Evaluation
    - Allows discovery of new requirements
  - Use
    - Prototype creates new requirements by changing work practice
- Prototypes are not mission-hardened
  - Inappropriate as product
    - Messy under the hood
    - "Layered" form evolution, and incomplete
  - Need to capture requirements in a document

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Requirements Benefits

- A Requirements Specification allows hand-off to production development team
- Some requirements cannot be implemented in current prototype due to early design choices
- Helps with transition to production and operations environment
- Aids identification and clarification of requirements which come out of prototype inspection

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Progress on WorkIT Requirements

- Analysis of design artifacts begun
- Specification format under development
  - Combining both high-level and "as-built" requirements
- Identification of requirements vs. design choices
  - Rationale capture by Design Team and developer
  - Non-implemented reqm'ts will be specified with less detail
- Will do example trace from design artifact to specification

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A Methodology for Generating Software Requirements from Prototyping: WorkIT Case

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Team Products and Requirements

- Implications for Design Team of need and designs
  - Products of design team needed for requirements
    - *General guidelines as well as specific design and implementation*
    - Interface, functional and back-end requirements
  - Team Products are Design Artifacts
    - Annotated Designs, Screen Shots
    - Alternative designs
    - Wish list for reimplementation is important source
    - Prototype as artifact
  - Rationale needed as prototype can't capture all requirements
    - Early design choices preclude implementation of some requirements

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3. Technology Infusion of Teamwork Tools

- Exploration Planning and Operations Center (ExPOC) use of WorkIT in NEEMO-5
- Preparation for operational evaluation of WorkIT version 4.0
- Logger evaluation
- Preparation for operational evaluation of Logger version 1.0

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WorkIT Evaluations

- BME walkthrough evaluation with some free use (videotaped) - WorkIT 2
- Stuffing the BME database with content from past issues (designers and feedback forms) – WorkIT 3
- ExPOC evaluation in training walkthrough for NEEMO-5 Mission (videotaped and feedback forms)
- ExPOC drop-in interview evaluation during NEEMO-5 Mission, June 2003
- BME evaluation in operational use – WorkIT 4 (Surgeon/BME in ISS Expedition 8)

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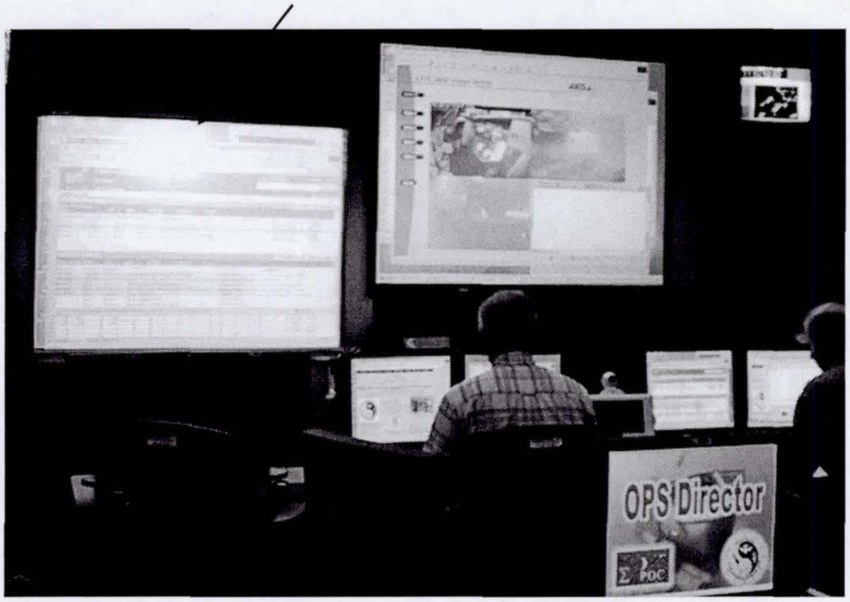
WorkIT in NEEMO-5



WorkIT support in NEEMO-5

- WorkIT prototype use and informal evaluation during the 6/03 NASA Extreme Environment Mission Operations (NEEMO-5) mission in ExPOC
  - NASA crew living in Aquarius Underwater Research Facility off the coast of Key Largo, Florida.
  - Practice for long-duration space habitation, research and construction, with undersea structures simulating Space Station assembly activities
- WorkIT tool provided information management and action tracking for the NEEMO topside operations teams at Johnson Space Center and in Florida
  - WorkIT was not specifically designed for this group of about 10 people
  - Primary use: Handling issues that involved assigning actions
- Evaluations
  - Videotaped training walkthrough that produced a wealth of feedback
  - Drop-in interviews and observations of three users during the mission
- Results
  - Surprised and delighted with automated services and low overhead
  - Found it intuitive and easy to use, even without using the tutorial
  - Found that it reduced rather than increased workload in handlingactions
  - Eager to use during upcoming missions and to help prepare for missions

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WorkIT 4.0

- New capabilities
  - NOTE item for entering a text item without attached file
  - Automatic creation of Status Report
  - More comprehensive search that includes Task Logs
  - WorkIT tutorial and Help system framework
- Improvement in
  - Feedback system (from users to developers)
  - Navigation and UI presentation
  - Capacity for handling large status and task logs
  - Error handling
- Accommodation of new configuration in Surgeon/BME database and server platform

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Console Logger 1.0

- Logger Objectives
- Logger Features
- Example Views (Quick Entries, Searches, Reports)
- Evaluation
- Future Plans

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Logger Objectives

- Support console logging tasks
  - Assist entry of common log note types
  - Assist in making complete, consistent entries
  - Search log notes based on topic, author, activity, discipline
  - Make logs available to flight controllers not on console
- Support report generation from log notes
- Make logger accessible to other console support agents
  - Automated log notes from telemetry, ELog messages (IBRA)
  - Integration with WorkIT, ReportMaker

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Logger Prototype Features

- Web based application (accessibility, user acceptance)
- Data base orientation
  - Each time-stamped entry is a separate record
  - Records organized by discipline and activity (flight increment, simulation)
  - Users can search entries by topic, author, discipline, activity
- ReportMaker integration
  - Selected log notes go to a specific part of the Handover Report, depending on the category assigned to them
  - Additional report types (Daily Summary) are definable
  - Reports are converted to Word format for printing
- Low effort entry for common types of log notes

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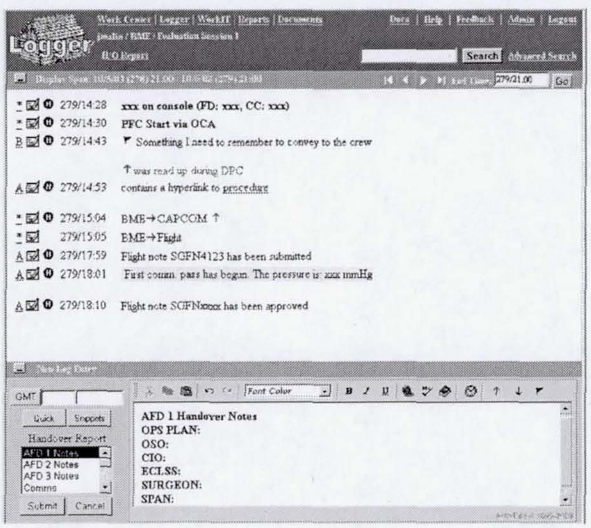
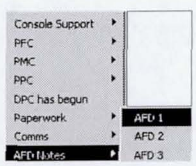
Assistance for Common Entry Types



- Quick menu selection
- Auto text entry
- Auto handover category marking
- No need to enter timestamp unless different from now



Quick menu

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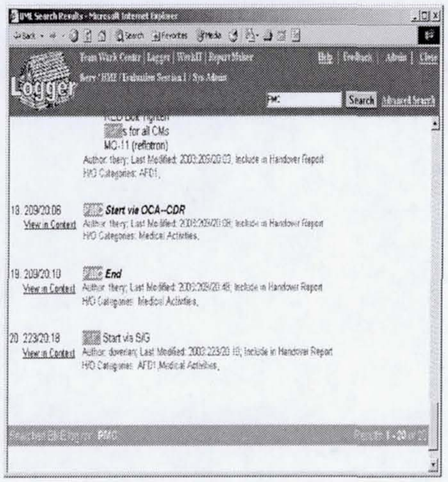
Logger Searches



- Basic search implemented
- Full info on "hits"
- Capability to view "hits" in context of other log notes on same shift
- Future: control search of time-frame, disciplines, activities; re-execute common searches

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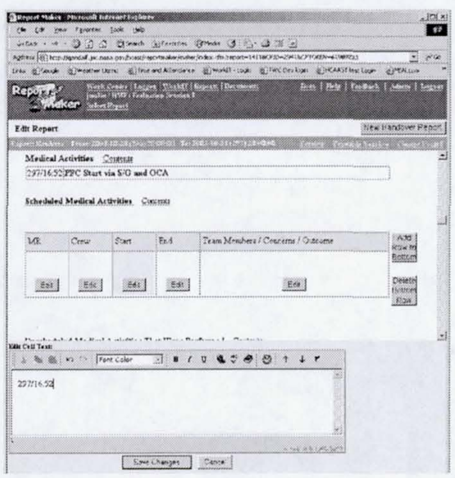
Automated Reports



- Report format specifies log entry queries to include in Handover Report
- Specific text entry areas allow direct input into report
- Later, reports are printable in Word format

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Logger Prototype Evaluation

- Purpose: Formative rather than summative
  - Identify improvements needed in prototype
  - Not to compare performance to other software
- Method: Demonstration (with flight controllers exercising the logger functions) and Interview
- Evaluators: Four flight controllers
- Videotaped for subsequent analysis of specific features
  - Timing of system responsiveness
  - Reviewing for points where user interactions were difficult

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Logger Progress/Plans

- Enhancements
  - Quick menu: New entries with fill-in formats for console support and AFD notes; arrow icon; highlighting
  - Snippets: Re-implemented to fix persistent bugs
  - Handover Report: Refined format for Surgeon/BME
  - Dedicated server to ensure fast system response
  - Help pages
- Surgeon/BME evaluation in mission simulations soon
- ExPOC evaluation in undersea mission soon
- Longer Range
  - Multi-discipline views of logs (e.g front and back room)
  - User interface for customizing menus and report formats
  - IBRA-base automated logging of routine, telemetry-based entries
  - Assistance for tracking paperwork, to-do lists (make use of artifacts from users)

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4. Demonstrations

- Simulation testbed
- FY02 Demonstration
- FY03 Demonstration
- Integrated Demonstration support

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Simulation Testbed

- Testbed simulates operation of life support system hardware (air and water systems)
  - Dynamically interacts with ISMAs, to test new ISMA capabilities in teamwork to intervene during anomalies
  - Capability to simulate combined, cascading and global effects of local problems
  - Case server (Java) utility saves and replays simulation cases
    - Capability to remotely pause and resume supports scripted dynamic interaction between ISMA and user in FY03 demo
- Enhanced biological water processor model will simulate more off-nominal scenarios
  - Uses generic library of components from Model-Based Hazard Analysis project (ECS program), to support broader variety of types of failures and degradations in system

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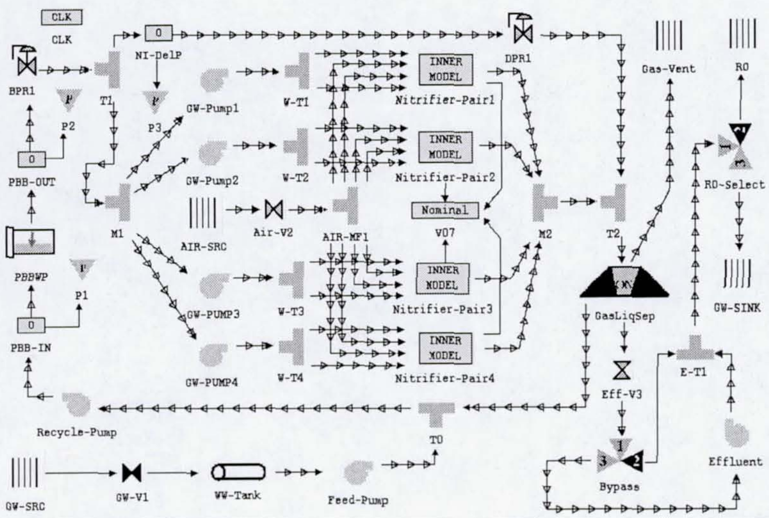
Model of Biological Water Processor



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Configurable Failable Components

- Styles of modeling failures and degradation
  - Discrete changes triggered by failures and problem inputs
    - Immediate or delayed changes to state, behavior mode or control regime
  - Continuous degradation triggered by failures and problem inputs
  - Nontemporal algebraic relations
    - Performance level affected by conditions
    - Failures to operate or change upon input: stuck flags
    - Random variation in measurement or input
- Degrading and regenerating processing performance
- Reactors and separators with multi-component mixtures
  - Add and remove contaminants in rapid fluid composition changes
  - Migrate products, gas or liquid to wrong outflow
  - Imbalance process with feed or flow reversal problems
- Resource providers with alternative methods for reacting to excessive demands from multiple loads
- Leaks as specifiable additions to simulation scenarios

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FY03 Demo

- ISMA autonomous control of air processing systems in space, with joint anomaly management
  - Mixed-initiative dialogue with ISMA to execute a leak test for Oxygen Generation System
    - Loose command and response leads to agreement on conditions and timing
- IBRA helps maintain situational awareness of system status and ISMA operations with manual intervention
  - Automatically carries out customizable instructions to collect and present information in web applications
  - Ground controllers easily specify and activate instructions
    - Leak Test Instructions - triggered act-whenever requests
    - Actions include Logging and Report on Leak Test timing and states
      - Start and complete conditions, test start and stop, level measures

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Demonstrated Benefits

- ISMA aids anomaly response and user intervention with mixed initiative dialogue
  - Basic support for moving from loose commanding to tight and complete plan
  - Supported by ISMA capabilities to delay and abort
- IBRA aids monitoring, logging and report generation for Leak Test intervention
- Tool suite provides basis for further teamwork on anomaly and knowledge capture
  - Reference materials and special and periodic reports
  - Searchable logs and action items with metadata
  - Customizable IBRA instructions

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Plans for FY04-05

- Continue process of spin off into mission operations
- Advance technology infusion (HCC) methods
  - Use of teamwork artifacts for prototyping and customizing
  - Requirements collection that influences prototyping methods
  - "Effortless specification" strategies for evolvable systems
- Advance collaborative agent capabilities
  - Mixed-initiative interaction for joint problem solving and command completion.
  - Safety conscious agents that use simulation for checking response plans and resuming interrupted operations

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