Adding MAAP5 Severe Accident Simulation to the South Texas Project Simulator
Projects Design Considerations

- Minimized Changes
  - Only changes to executive and interface routines
  - No changes to basic physics models

- Interface MAAP5 to other FSS systems
  - MAAP5 usages for SAS training
  - Preselect MAAP5 ICs

- Integrate MAAP5 within L-3 MAPPS Simulation Environment
  - Real-time synchronization
  - Simulator Maintenance
**Modeling**

**L3 Mapps Modeling Tool**

- **Orchid ME** (Graphical Object Oriented Modeling)
  - Thermal–Hydraulic ANTHEM

- **Severe Accident Modeling**
  - **Design Code**
    - **MAAP5** (Modular Accident Analysis Program)
      - Change in Geometry of the fuel or surrounding structure
      - Provided under License by EPRI
      - MAAP has been used for two decades in PRA accident analysis and has been benchmarked against the TMI-2 and Fukushima-Daiichi, as well as other severe accident codes
      - MAAP code simulates fuel damage/melting, including clad oxidation, hydrogen generation, vessel failure, containment failure, and fission product release

- Real Time Simulation of both single and two-phase flow under all plant operating condition

  - Normal and Abnormal Condition
  - Major Transients
  - Mid Loop Operation
  - No change in the geometry of the fuel or surrounding structure
MAAP5 Integration

• MAAP5 models will be frozen during training
• MAAP5 will be enabled only during SAS
• Adapted version MAAP5 will run under the control of Orchid SE
• ICs, Malfunction, and Remote will be managed my Orchid IS
• 2-D and 3-D Visualization
• The Simulator Executive, which is responsible for dispatching all simulator programs, calls the synchronization module that controls the execution of MAAP 5. MAAP 5 runs as an external program.

• The existing MAAP 5 database is retained and all internal communication between MAAP 5 subroutines is performed through existing common blocks and database access routines.

• All common block MAAP 5 variables are put in a “shadow” CDB.

• These “shadow” CDB variables are assigned to the corresponding MAAP 5 common block variables at every time step.

• Interface modules read the MAAP 5 output variables from the shadow CDB; calculate the MAAP 5 input variables and write them to the shadow CDB.

• The MAAP common block will be assigned the values of the shadow CDB.

• MAAP runs its program in the next iteration using the updated MAAP input variables and the cycle continues.
Severe Accident Simulation Architecture

- No external ICs Needed or restart files on the MAAP 5 side
- Ensure Compatibility with existing FSS instructor Station
- Modified PMAAP to run within the simulator environment
There are four types of interfaces between the simulation models and MAAP 5:

1. **Process interfaces**
   All L3M simulator models with process interfaces to the systems that are replaced by the MAAP 5 models during SAS will interface the MAAP 5 via bidirectional interface objects on the appropriate Orchid® schematics.

2. **Logic interfaces**
   Any required output actuation signals coming from the simulator’s I&C models, which are required inputs to devices that are simulated in the MAAP 5 models (RCP pumps, PORVs, etc.), will be mapped via logic interfaces to the appropriate MAAP5 external event flag.

3. **Instrumentation interfaces**
   Instrumentation interfaces are outputs from MAAP 5 models required to drive process sensors in the Simulator. The MAAP 5 output variables will be connected to switching objects which are connected to the sensors. These switching objects permit switching the inputs to the sensors from simulator models to MAAP 5.

4. **Malfunctions and remote functions** (instructor actions)
   Malfunctions and remote functions are inputs to MAAP 5. The corresponding MAAP 5 variable will be set inside the input interface module.
MAAP5 Variable Mapping

• Mapping between MAAP 5 and MAAP 5 interface variables are done in the interface modules `maapi.for` and `maapo.for` and hence establishing the links between MAAP 5 and the rest of the simulator

• Maapi.for consists of all the input interfaces to MAAP 5
  • MAAP5 Events
  • MAAP5 Malfunctions and Remote Functions
  • MAAP5 Hydraulic inputs from the rest of the simulator

• Maapo.for consist of all the output interfaces from MAAP5
  • MAAP5 hydraulic outputs to the rest of the simulator
  • MAAP5 outputs to sensors and instrumentation
Orchid Instructor Station

![STPDEV01 - Orchid Instructor Station](image)

<table>
<thead>
<tr>
<th>Description</th>
<th>Config</th>
<th>Originator</th>
<th>MAAP Mode</th>
<th>RCS TAWS</th>
<th>Core Exit</th>
<th>Reactor Power</th>
<th>Steam Press</th>
<th>Press Level</th>
<th>Gen MW</th>
<th>Press Press</th>
<th>Sys Boron</th>
<th>Time to Live</th>
<th>Xenon</th>
<th>Core Wide Rx</th>
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</table>
• Instructor Interface (Orchid IS)
• Manage Initial conditions and malfunction
MAAP5 Integration

OrchidME Structure

New MAAP Library

VAR_RCS
Network Variables for MAAP NSSS

LIBRARY: maap

DESCRIPTION: var_rcs is used to generate the cdv variables required for interfaces between MAAP - L3M's hydraulic model.

Each MAAP "sub-system" must use a separate var_rcs object. For example, MAAP RCS and MAAP SG must use a separate var_rcs object.

Connection: - none

Initialize the following parameter before build **important**: - XNNODE - MAAP NUMBER OF NODES (ARRAY SIZE) - XNSRC - MAAP NUMBER OF SRC FLOWS (ARRAY SIZE)

Related objects: - var_cvtm: object to generate cdv variables for MAAP interfaces for NSSS etc.

MODELING APPROACH

var_rcs is used to generate the cdv variables required for interfaces between MAAP - L3M's hydraulic model.
FSS and MAAP Integration

MAAP Object Documentation

WSRC1P_MI
MAAP Input Interface with 1-ph External Source Flow

Library: maap
Description: wsrlp_mi is used to establish the flow source input interface with MAAP from the 1-ph system P node.

SELECTB_MO
Switch for Binary Inputs

Library: maap
Description: selectb_mo is used to switch the input from L3M to MAAP for binary signals.

SELECTA_MO
Switch for Analog Inputs

Library: maap
Description: selecta_mo is used to switch the input from L3M to MAAP before sending the signal to a sensor.

WSRC1P_MO
MAAP Output Interfaces with 1-ph External Source Flow

Library: maap
Description: wsrlp_mo is used to establish the flow source output interface with MAAP from the 1-ph system P node.

Shows how the object is used
FSS and MAAP Integration

Schematic: RC_MAP_01
NOTE:

INP1: From FSS Schematic
INP2: From MAAP Schematic

OUT3: To FSS Schematic
FSS and MAAP Integration

18 New MAAP / Flex Schematics > 5 New Groups
Schematic: map_x_08
FSS and MAAP Integration

Schematic: map_x_08
Schematic Change I/F To MAAP SFP

Schematic: bcp001
Overall Interface Scheme: Between L3M’s models and MAAP running
Severe Accidents Scenarios

1) Criticality control
   a. ATWS + Turbine trip + MSIV + TDAFW/MDAFW
   b. ATWS + Boration

2) Core cooling at high pressure
   a. Feed & Bleed
   b. SBO + TDAFW + SG Main steam ADV

3) Core cooling at low pressure
   a. LOCA + FLEX RCS Shutdown Makeup pump via SI system
   b. Loss of RHR at power and shutdown mode with core cooling with AFW available through feeding and steaming SG’s

4) Loss of ultimate heat sink
   a. SBO + Alternate Containment cooling

5) Containment cooling
   a. SBO + Alternate Containment Cooling

6) Molten core cooling
   a. Use procedure path SAG-8, Flood Containment

7) Prevention of Hydrogen Explosion
   a. Reduce Containment hydrogen with Electric Hydrogen Recombiner

NOTE: Simulated by L3M models and not the MAAP model. Recombination of hydrogen and oxygen is part of the FSS model since the concentration of H2 and O2 are dynamically transported between each control volume, based on the flow rate between those volumes.

8) Loss of SFP cooling
   a. FLEX SFP makeup pump water injection by using RWST as source
FSS and MAAP Integration
• SG Makeup
• RCS Makeup
• RCS Makeup Strategy (modes 5 & 6)
• Spent Fuel Pool (SFP) Makeup
• FLEX Power
• Water Makeup Strategy for RWST, AFWST, and DA Storage Tank
FSS and MAAP Integration
FSS and MAAP Integration

FLEX02

FLEX SG MAKEUP PUMP 11

FLEX SG MAKEUP PUMP 12
FSS and MAAP Integration
FLEX DP1000

FR Load Distribution Panel DP1000 (sc_FLEX_ELEC)

FR DIESEL GENERATOR #11
- DG11CB CB1001
- DG11 2000AF

FR DIESEL GENERATOR #12
- DG12CB CB1002
- DG12 2000AF

NRSC TG 4160 GENERATOR
- 4.16K BUS E1A
- 4.16K BUS E1B
- 4.16K BUS E1C

MCC-10B 480V
- 400AF 150AT
- 600AF 250AT
- 400AF 200AT
- 400AF 175AT
- 400AF 150AT

MCC-10K 480V
- 250AF 70AT
- 250AF 70AT
- 250AF 80AT
- 250AF 125AT

MCC-10B 480V
- 250AF 100AT
- 250AF 100AT
- 250AF 150AT
- 250AF 125AT

FLEX RCS MAKEUP PUMP #13
- FLEX RCS MAKEUP PUMP #11
- FLEX RCS MAKEUP PUMP #12
- FLEX RCS MAKEUP PUMP #14
- FLEX RCS MAKEUP PUMP #16
- FLEX SFP MAKEUP PUMP #15
- CVCS CHARGING PUMP 2A
- 120V LTR14L DIST. PANEL
- 120V LTE14U DIST. PANEL
- 480V LOAD CENTER E1C4
- 480V LOAD CENTER E1C2
- 480V LOAD CENTER E1A2
- 480V LOAD CENTER E1A4
- 480V LOAD CENTER E1B4
FLEX PUMPS
## Tests

### NETs - Normal Evolution Tests

<table>
<thead>
<tr>
<th>NET</th>
<th>Description</th>
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<tbody>
<tr>
<td>NET 1</td>
<td>Plant Shutdown 100% to Mode 3</td>
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<tr>
<td>NET 2</td>
<td>Plant Cool Down Mode 3 to Mode 5</td>
</tr>
<tr>
<td>NET 3</td>
<td>Mid-Loop Operations</td>
</tr>
<tr>
<td>NET 4</td>
<td>Plant Heat up</td>
</tr>
<tr>
<td>NET 5</td>
<td>Plant Startup to 100%</td>
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### SST - Steady State Stability and Accuracy Tests

<table>
<thead>
<tr>
<th>SST</th>
<th>Description</th>
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<tbody>
<tr>
<td>SST 1</td>
<td>100% RTP Steady State Stability</td>
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<tr>
<td>SST 2</td>
<td>100% RTP Steady State Accuracy</td>
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<tr>
<td>SST 3</td>
<td>75% RTP Steady State Accuracy</td>
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<tr>
<td>SST 4</td>
<td>50% RTP Steady State Accuracy</td>
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<tr>
<td>SST 5</td>
<td>28.9% RTP Steady State Accuracy</td>
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### TT - Transient Tests

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<tr>
<th>TT</th>
<th>Description</th>
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<tbody>
<tr>
<td>TT 1</td>
<td>Manual Reactor Trip from 100% RTP</td>
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<tr>
<td>TT 2</td>
<td>Simultaneous trip of all Main Feed Pumps</td>
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<tr>
<td>TT 3</td>
<td>Simultaneous Closure of All MSIVs</td>
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<tr>
<td>TT 4</td>
<td>Simultaneous Trip of all Reactor Coolant Pumps</td>
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<tr>
<td>TT 5</td>
<td>Single RCP Trip from below P-8</td>
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<td>TT 6</td>
<td>Main Turbine trip from below P-9</td>
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<td>TT 7</td>
<td>Load rejection</td>
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<tr>
<td>TT 8</td>
<td>Loss of Coolant Accident with Concurrent loss of offsite power</td>
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<tr>
<td>TT 9</td>
<td>Design Basis Main Eilem Line Break</td>
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<tr>
<td>TT 10</td>
<td>PDRV Leak with no high Head Safety Injection</td>
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<tr>
<td>TT 11</td>
<td>Loss of all Main and Auxiliary Feedwater</td>
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</table>

### PROCEDURES

- 0POP12-ZO-FSG01  LONG TERM RCS INVENTORY CONTROL
- 0POP12-ZO-FSG03  ALTERNATE LOW PRESSURE FEEDWATER
- 0POP12-ZO-FSG04  ELAP DC BUS LOAD SHED/MANAGEMENT
- 0POP12-ZO-FSG05  INITIAL ASSESSMENT AND FLEX EQUIPMENT STAGING
- 0POP12-ZO-FSG06  ALTERNATE AFWST MAKEUP
- 0POP12-ZO-FSG07  LOSS OF VITAL INSTRUMENTATION OR CONTROL POWER
- 0POP12-ZO-FSG08  ALTERNATE RCS BORATION
- 0POP12-ZO-FSG09  LOW DECAY HEAT TEMPERATURE CONTROL
- 0POP12-ZO-FSG10  RCS ACCUMULATOR INJECTION ISOLATION
- 0POP12-ZO-FSG11  ALTERNATE SFP MAKEUP AND COOLING
- 0POP12-ZO-FSG12  ALTERNATE CONTAINMENT COOLING
- 0POP12-ZO-FSG13  TRANSITION FROM FLEX EQUIPMENT
- 0POP12-ZO-FSG14  SHUTDOWN RCS MAKEUP
- 0POP12-ZO-FSG17  PORTABLE PUMP FILL OF RWST
- 0POP12-ZO-FSG19  480V FLEX DIESEL GENERATOR OPERATION
- 0POP12-ZO-FSG20  ALTERNATE QDPS PARAMETER MONITORING
- 0POP12-ZO-FSG21  NSRC TURBINE GENERATOR

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Scenario Manager
2-D and 3-D Visualization
2-D and 3-D Visualization

Figure 8-10 Color Range Setup
2-D and 3-D Visualization
2-D and 3-D Visualization

Figure 8-13 Typical NSSS 2-D Graphic Page
Summary

• 5 groups > 15 MAAPS Schematics added
• 3 FLEX Schematics
• 2-D and 3-D Graphics
• Active Schematics
• 2 programs Maapi.for Maapo.for
• MAAP point addition to psim2 database
• Additional Instructor Station Remotes and Malfunction
• No New Maintenance tool needed to maintain the simulator