Modeling Failure Modes with SysML

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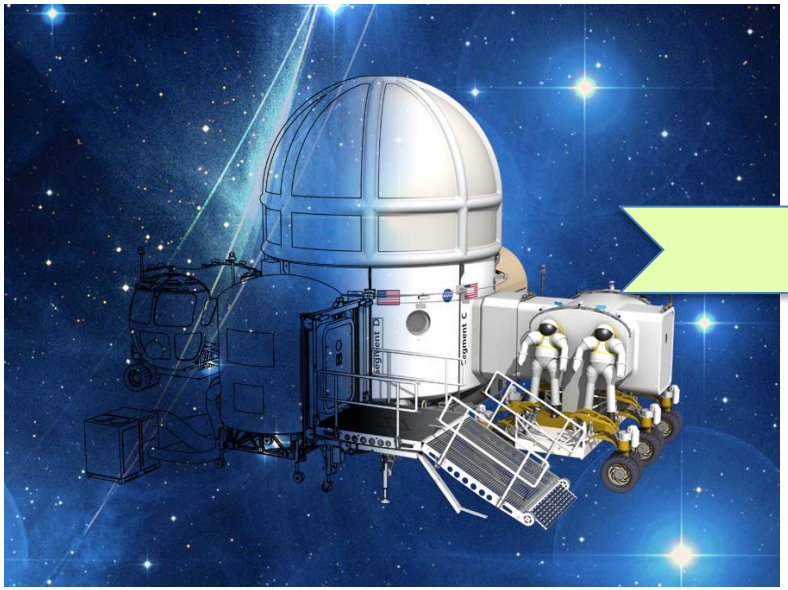
Problem

- Spacecraft design and operation stakeholders are creating models/artifacts of the same system with different processes, tools, and representations.
- These oft uncoordinated approaches create locally successful products but also create a communication barrier among the various stakeholders (the “Tower of Babel” Effect).
- The same information is captured multiple times, in multiple places, with multiple representations, creating a maintenance challenge.

Habitat Demonstration Unit (HDU) Project Description

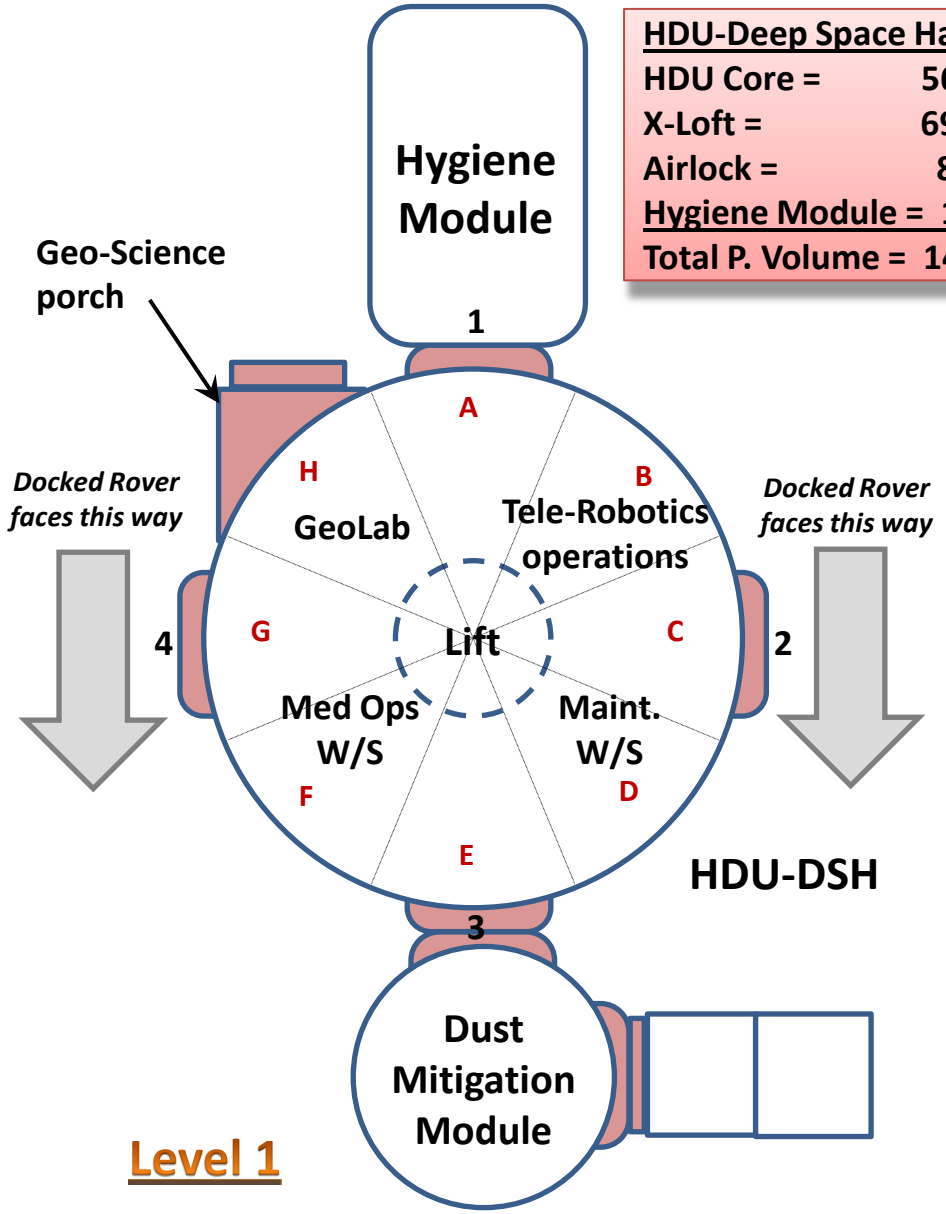
- Multi-center Technology Investment Project started in 2010.
- Objectives
  - Evaluate and validate Lunar Surface System (LSS) Habitat Concept efficiency and effectiveness
  - Build, integrate, test, and evaluate the vertical hab configuration utilizing developmental hardware & software



HDU-DSH Technology & Innovations Demonstrations & Evaluations – 2011

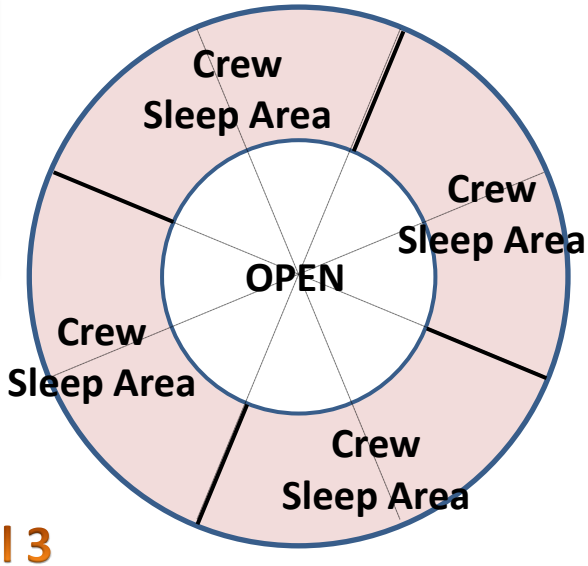
1. **Inflatable Loft (X-Hab Competition)**
2. **Logistics-to-Living**
3. Autonomous Ops: "Intelligent" Habitat System Management Software
   - **A. Advanced Caution & Warning System and Procedure Execution**
4. **iHab Digital Double (D^2)**
5. **Power management systems**
6. **Environmental Protection Technologies**
   - **A. Dust Mitigation Technologies**
     - **a. Electrodynamic Dust Screen to repel dust from surfaces**
     - **b. Lotus Coating**
     - **c. Vent Hood at the General Maintenance Workstation**
     - **d. Operational Concept for End-to-End Dust Contamination Management**
     - **e. Vacuum Cleaner**
   - **B. Micrometeoroid Mitigation Technologies**
     - **a. Micrometeoroid Detection**
   - **C. Radiation**
     - **a. Operational Demonstration of Cargo Transfer Bags to deployable blankets for Radiation Protection**
7. **HDU Core Computing, Wireless Communication and RFID**
8. **Standards-based Modular Instrumentation System: Wireless Sensor Nodes**
9. **Flat Surface Damage Detection system**
10. **MMOD Hab impact monitoring system**
11. **Telerobotic Workstation**
12. **General Maintenance/EVA Workstation**
13. **Medical Ops/Life Science Workstation**
14. **Geo-Science Lab Glovebox/Workstation**
15. **Material Handling**
16. **Food Production: Atrium concept**
17. **LED Lighting**
18. **3-D Layered Damage Detection System for Surfaces**
19. **Habitability / Habitation**
20. **Hygiene Module**

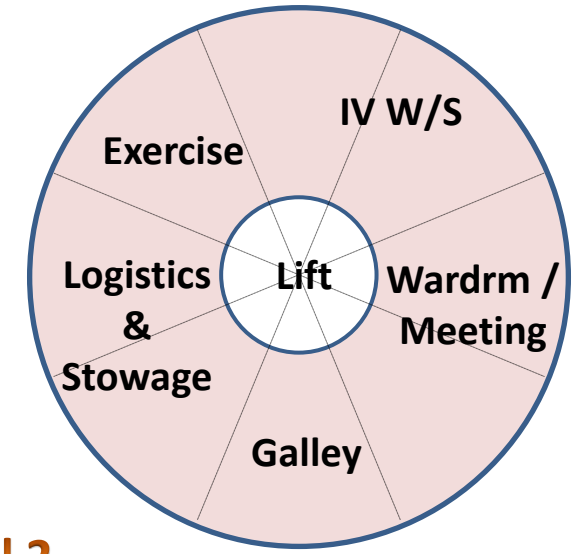
HDU-DSH Plan Views



HDU-Deep Space Hab:

HDU Core =	56.0 m^3
X-Loft =	69.9 m^3
Airlock =	8.6 m^3
Hygiene Module =	14.1 m^3
Total P. Volume =	148.1 m^3



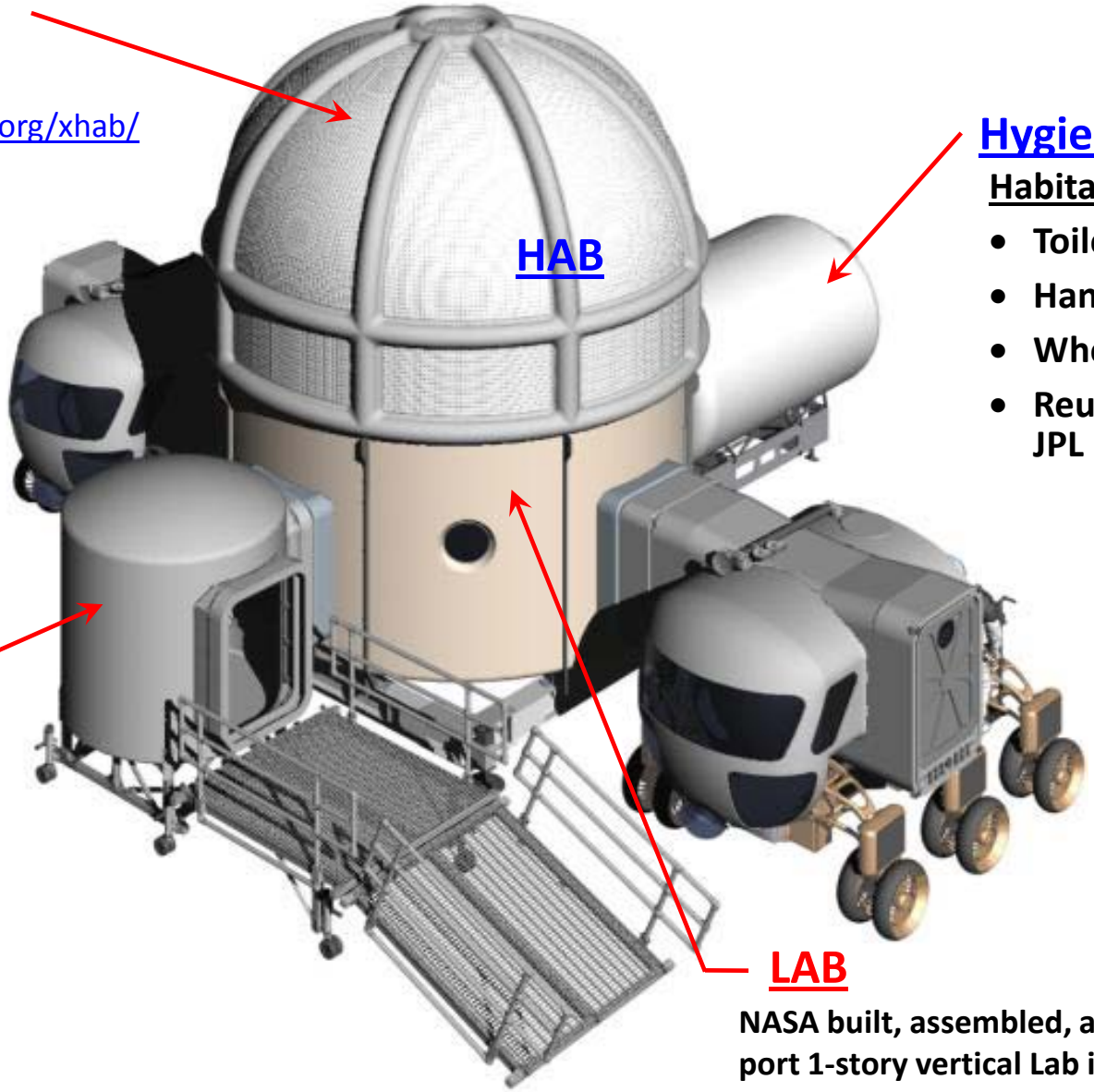


FY11 HDU-DSH Configuration

X-Hab Challenge

Inflatable "Loft"

http://www.spacegrant.org/xhab/



Hygiene Module

Habitat Innovation

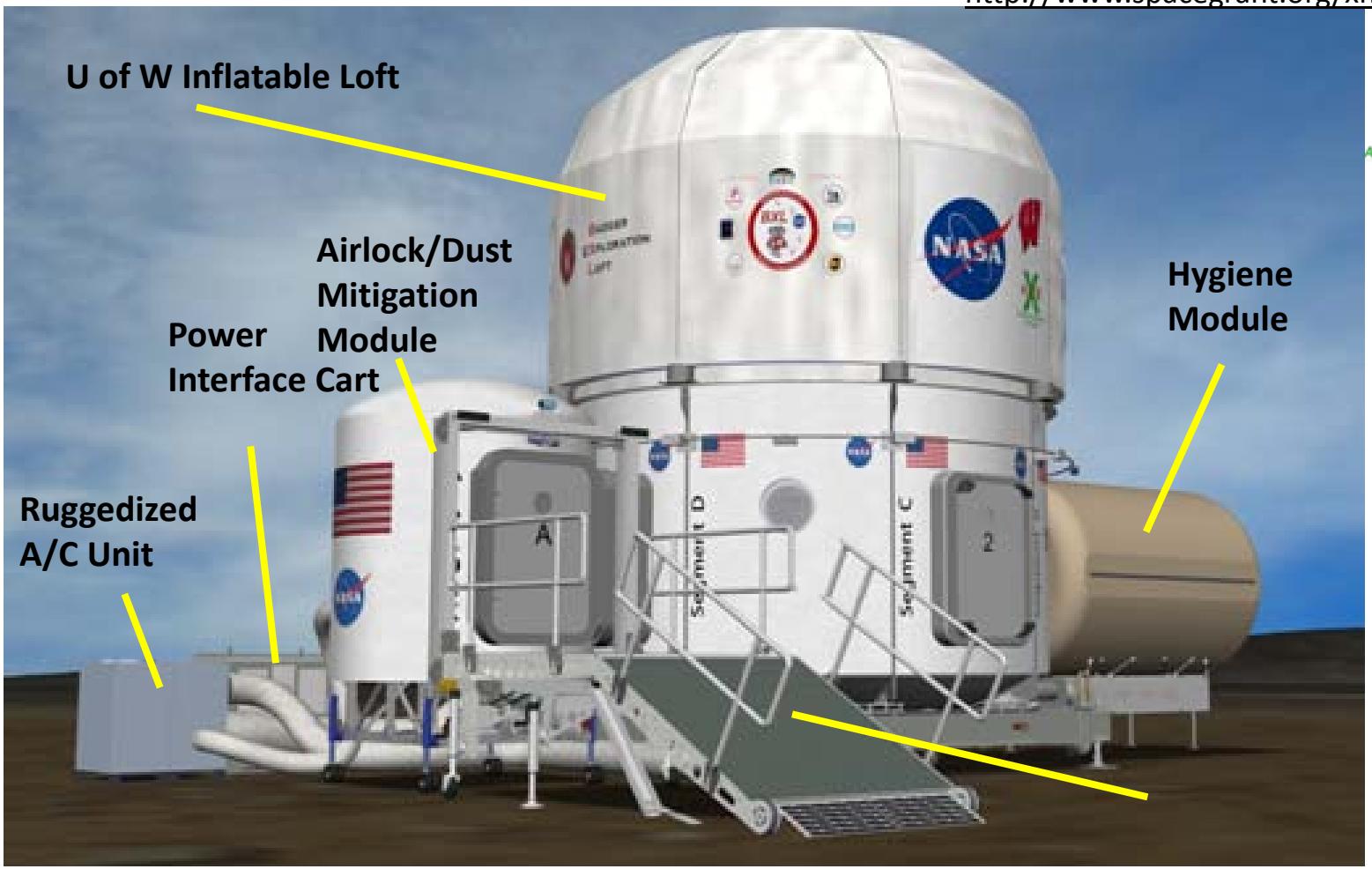
- **Toilet**
- **Hand Wash**
- **Whole Body Wash**
- **Reuses shell from JPL MicroHab**

Airlock / Dust Mitigation module

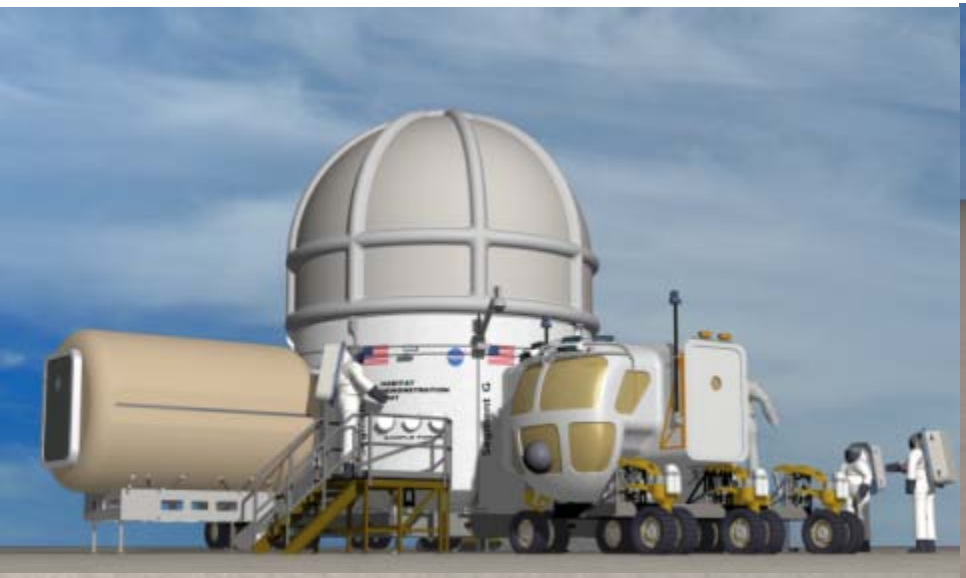
NASA built, assembled, and outfitted a 4-port 1-story vertical Lab in FY10

HDU Reconfiguration to DSH

http://www.spacegrant.org/xhab/

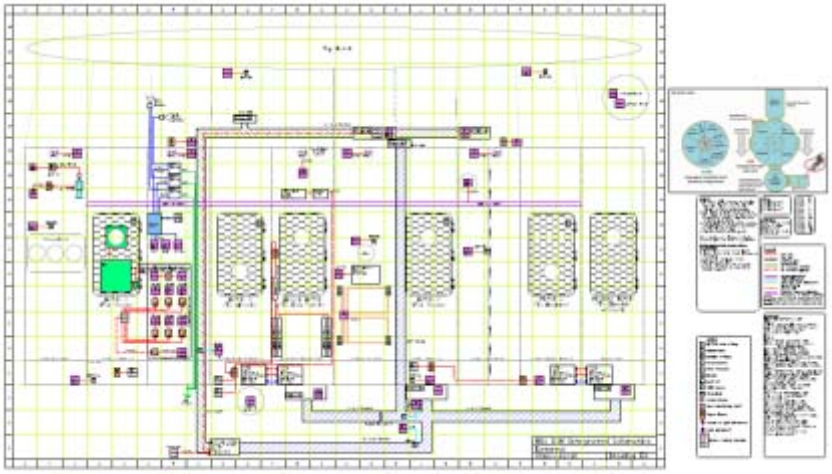


HDU-DSH Views

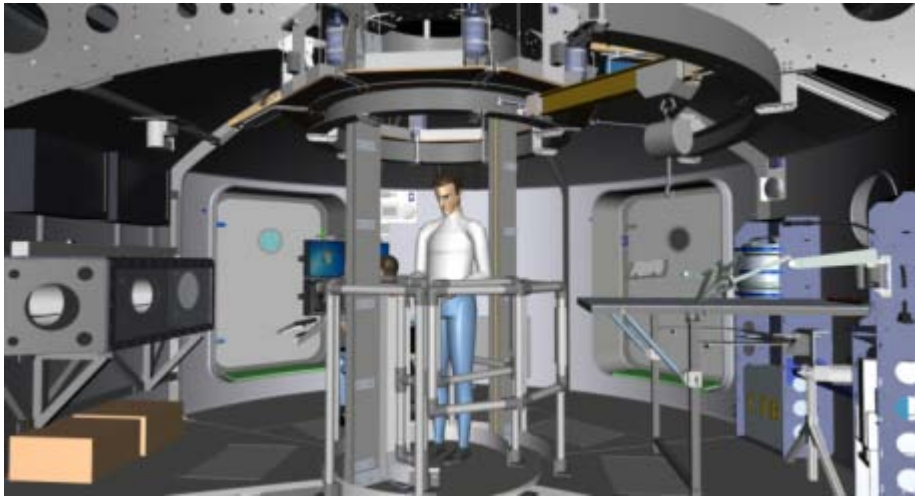


DSH Systems Integration

CAD Integration invaluable in integrating lift platform with material handling system, lighting, atrium, existing hardware, and access between the two levels



Integrated Schematics invaluable in developing Digital Double Representations of DSH systems and interfaces



Assembly and Integration

Installation of Material Handling System and Atrium

New Power Cart to Facilitate Utilization of Facility, Generator, or Green Power Tech Demos

Outfitting of the Hygiene Module

Tele-Robotic Work Station

Integration of Suit Maintenance capability into General Maintenance Work Station

Checkout of Ruggedized Heat Pump for Analog Test Operations

Installation of New Electrical Interfaces for Hygiene Module

Test Operations

- Desert RaTS 2011 was successfully completed 8/25/11-9/14/11.

HDU Artifacts by multiple Stakeholders

Telemetry and Command

Mission Operation Planning

Simulation

CAD Drawings

Electronic Procedure

System Displays

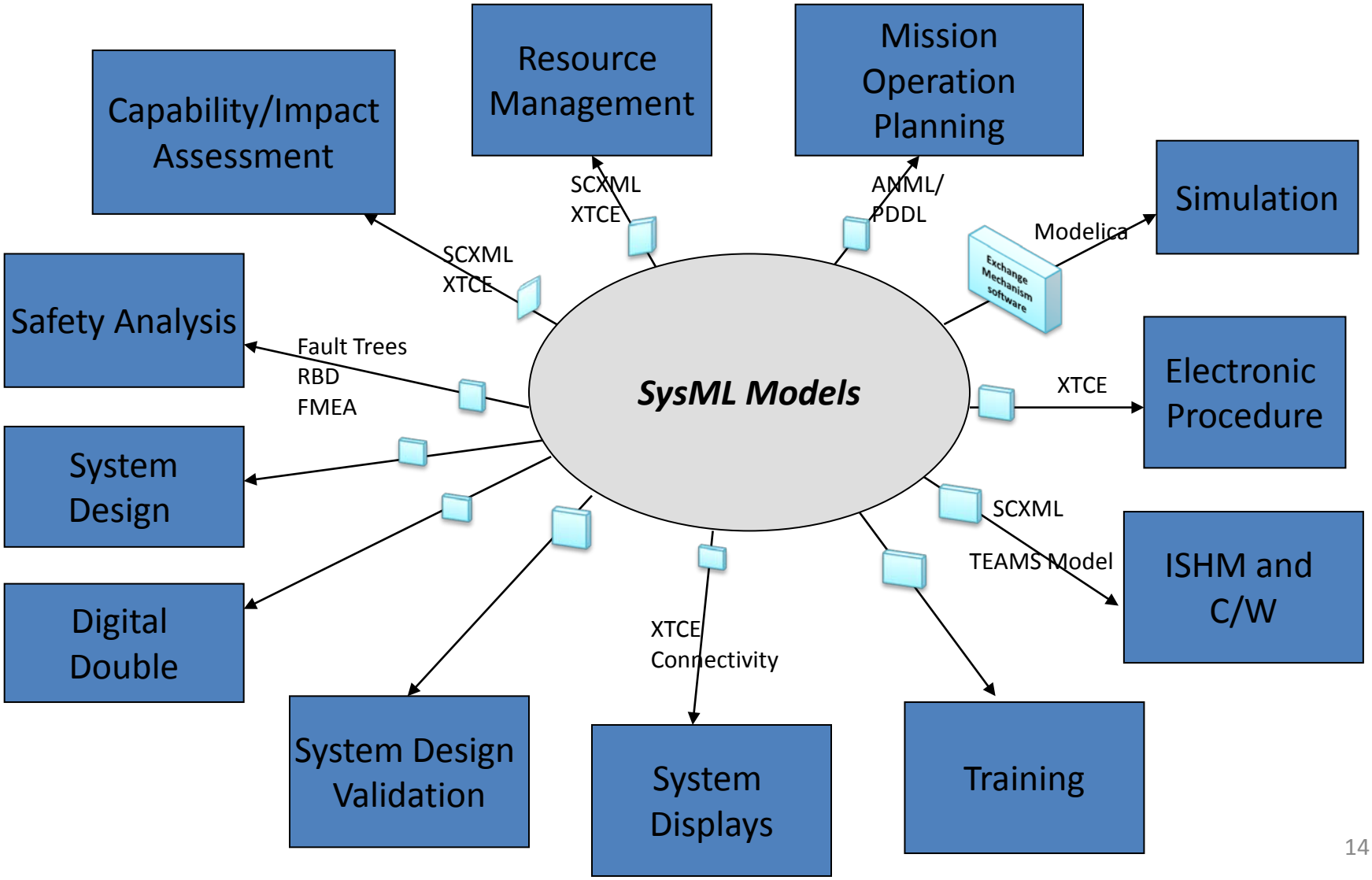
ISHM and C/W

Proposed HDU Solution

- Build Habitat Demonstration Unit (HDU)/Deep Space Habitat (DSH) SysML Model
  - Detailed SysML models of all subsystems including the full set of structural and behavioral models from HDU paper artifacts
- Derive Models
  - System connectivity representation in a database
  - XTCE capturing Telemetry and Commands for electronic Procedure software
  - Fault Management Artifacts (FMEAs, RBDs, TEAMs model, etc)
- Develop Exchange Mechanisms Software
  - Initial set of software that translate the models from SysML to other languages/models such as XTCE for Command and Telemetry, Modelica for Simulation, TEAMS models, FMEA, etc…

Uses of System Models

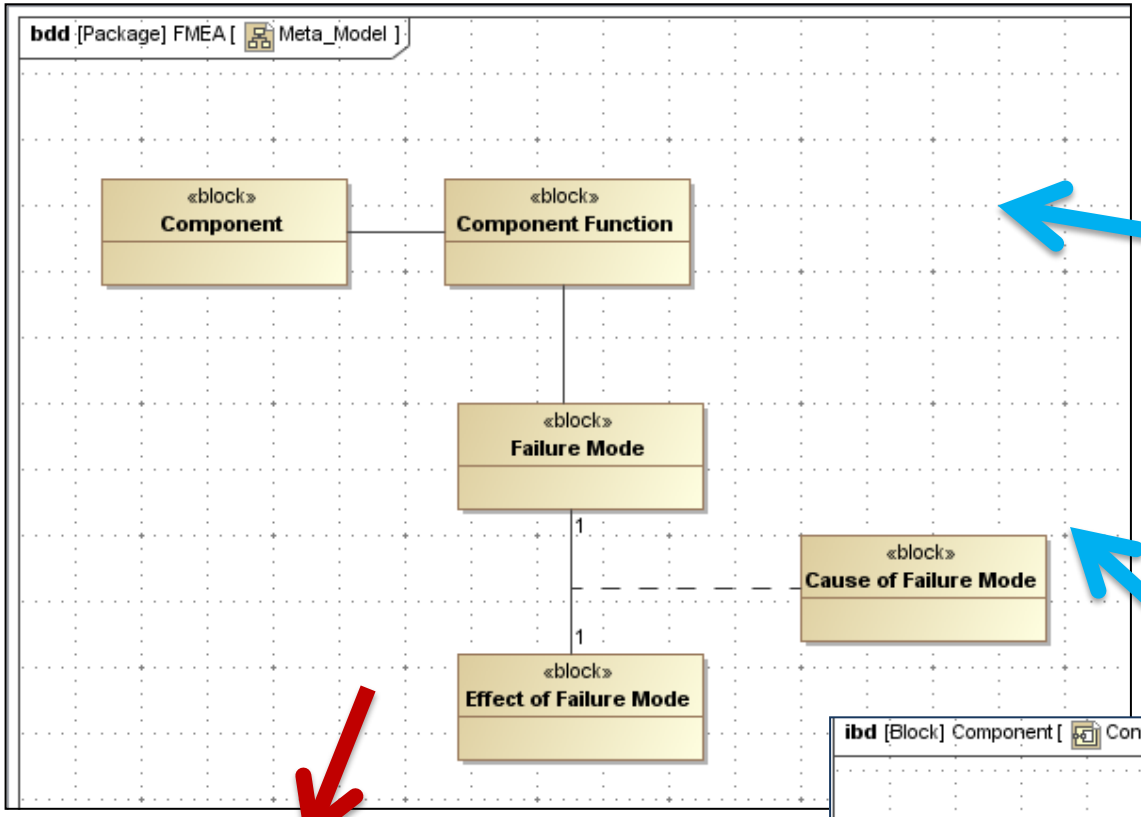
Model once and Use many times

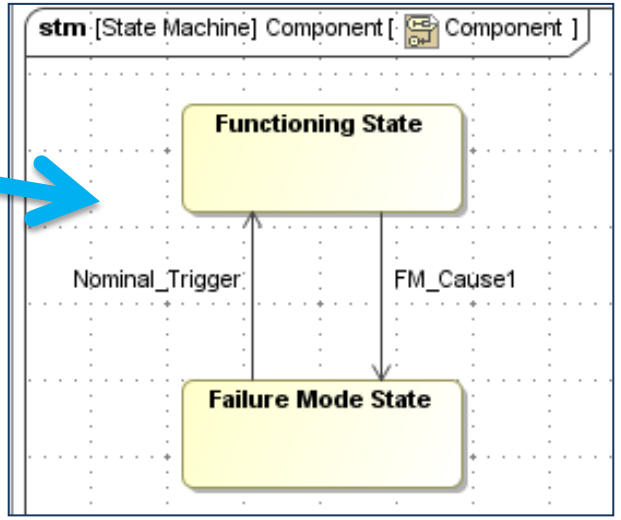


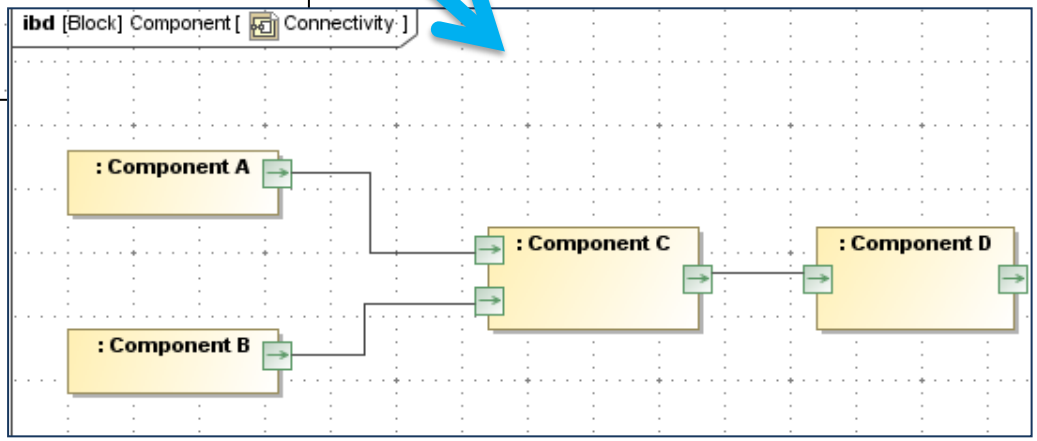
Current HDU SysML Modeling Status

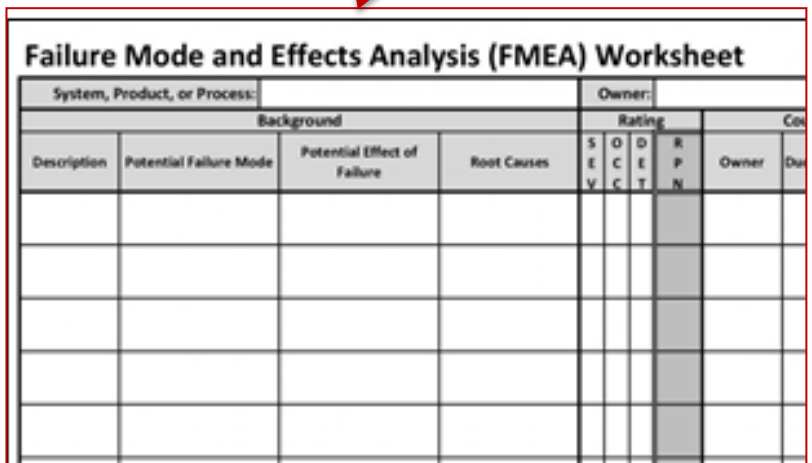
- Modeled the following HDU elements:
  - Subsystems (Power, ECLSS, Cameras, Lights, WSN, Avionics, etc)
  - System connectivity (power, data, and control)
  - commands and telemetry
  - state machines
  - component function and associated failure mode, cause, and effect
- Initiated library of re-usable component models
- Created plug-ins to generate artifacts from SysML models (MagicDraw):
  - Component/master equipment list from Subsystems
  - connectivity information (CSV)
  - XTCE
  - SCXML
  - FMEA artifacts

SysML Meta_Model for FM Artifacts





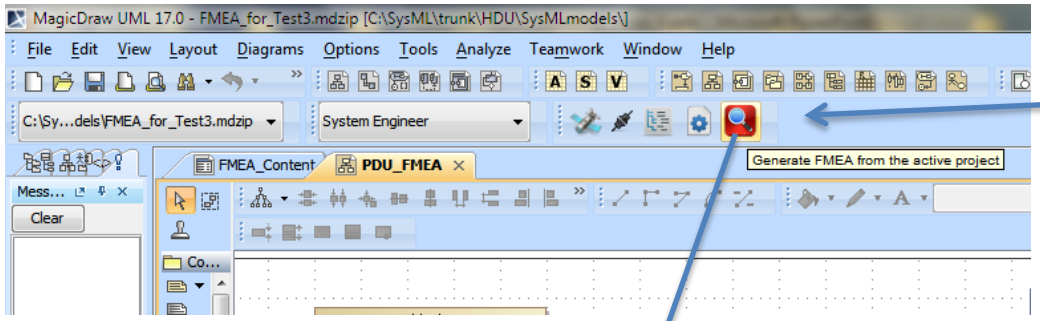


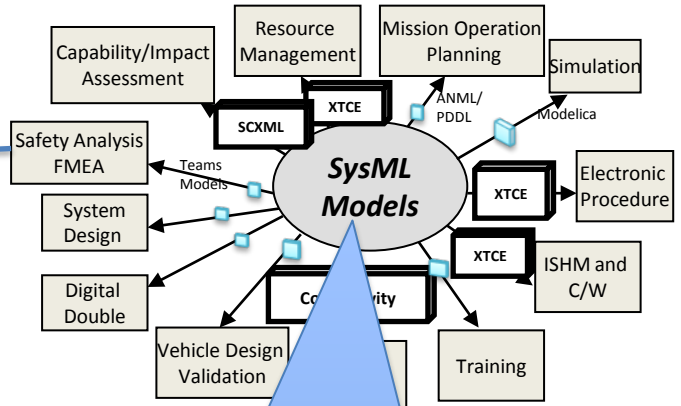


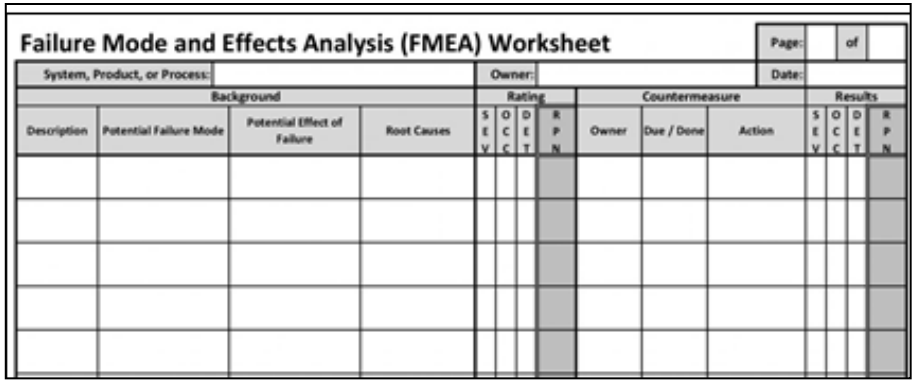
Failure Mode and Effects Analysis (FMEA) Worksheet

System, Product, or Process:				Owner:						
Background				Rating						
Description	Potential Failure Mode	Potential Effect of Failure	Root Causes	SEV	OCC	DET	RPN	Owner		

Fault Management Exchange





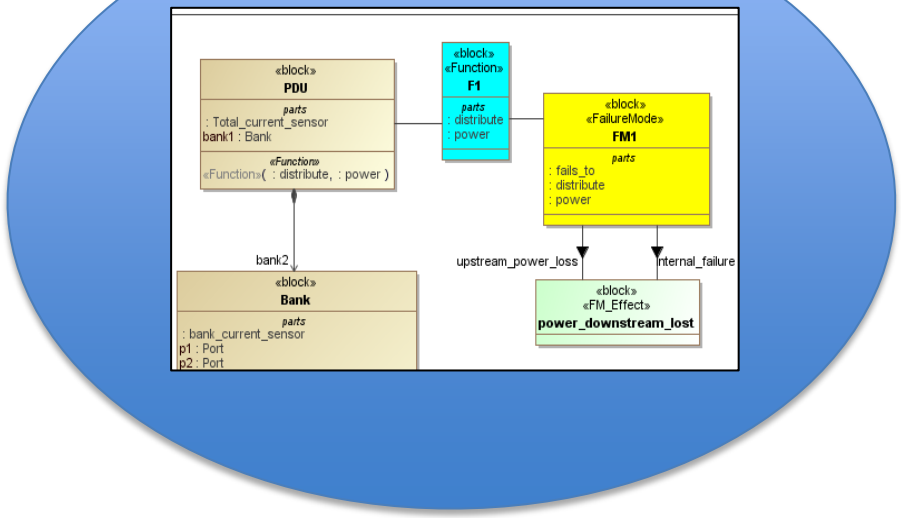


Failure Mode and Effects Analysis (FMEA) Worksheet

Page: of

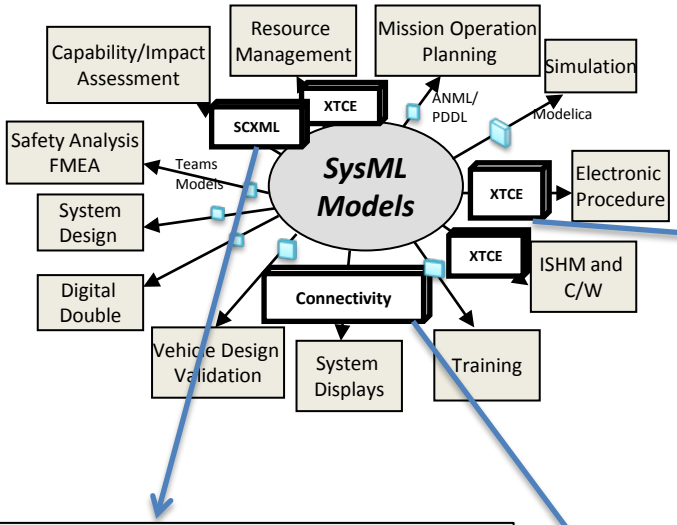
System, Product, or Process: Owner: Date:

Background				Rating				Countermeasure			Results			
Description	Potential Failure Mode	Potential Effect of Failure	Root Causes	SEV	OCC	DET	RPN	Owner	Due / Done	Action	SEV	OCC	DET	RPN



Other Exchange Examples

Magic Draw Plug-Ins



XML Telemetric and Command Exchange (XTCE) : OMG standard for Spacecraft T&C

```
<SpaceSystem name="RIU2">
    <AliasSet>
     <Alias alias="02" nameSpace="id"/>
     <Alias alias="020602" nameSpace="interface"/>
    </AliasSet>
    <Header classification="INTERFACE"/>
    <TelemetryMetaData>
     <ParameterSet>
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shortDescription="GEOLAB_GB_HUMIDITY1_DEWPOINT_SENSOR" name="020602018001">
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       </ParameterProperties>
      </Parameter>
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       <ParameterProperties dataSource="telemetry">
        <SystemName>CORE.GEOLAB.RIU2.VALIDIDY.1</SystemName>
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```
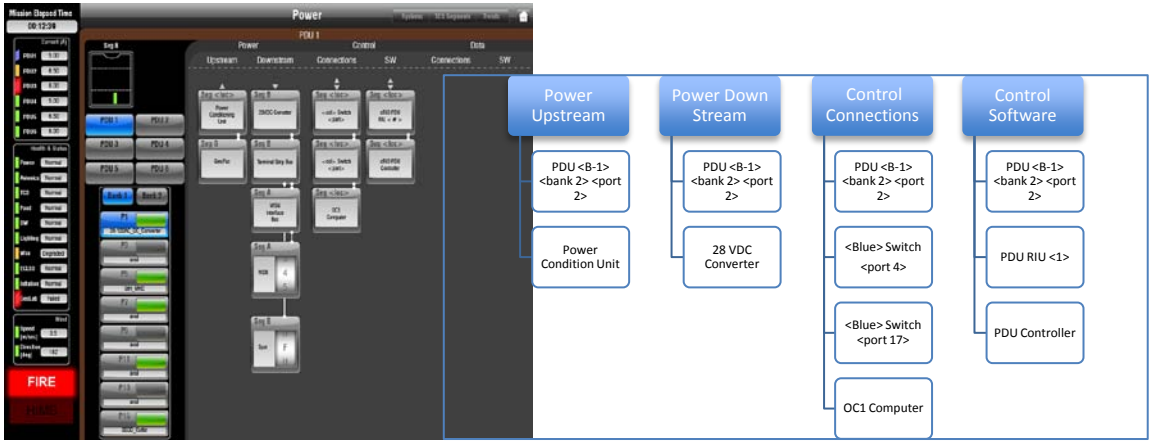

SCXML:"State Chart extensible Markup Language". Provides a generic state-machine based execution environment based on Harel State Tables.

```
<state id="S" initial="s1">
 <state id="s1" initial="s11">
<onexit> <log expr="'leaving s1'"/> </onexit>
<state id="s11">
<onexit> <log expr="'leaving s11'"/> </onexit>
</state>
<transition event="e" target="s21">
<log expr="'executing transition'"/>
</transition>
```



Future Work

- Further develop SysML to FMEA Generation and FMEA to SysML Import
- Generate RT-TEAMS model (caution and warning system)
- Explore the use of ModelicaML as an extension to the SysML models
- Explore generation of GUNNS (General Use Nodal Network Solver)/Trick manager
- Explore generation of ATML from SysML model
- Maturation of the NASA SysML Foundation profiles by
  - Extending the habitation models to includes additional stakeholders such as SMA, Mission Operation Training, V&V
  - Selecting new exemplar project domains to ensure coverage of different domains
    - Spacecraft human/unmanned
    - Robotics
  - Develop more exchange mechanisms software to translate from SysML to many stakeholders models/information format
- Delivery Processes, Tools to enable support for “significant” GFE project development

HDU SysML Demo

EXTRA SLIDES

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