Lunar Surface System Avionics Study Report to U.S. Chamber of Commerce

Ted Bonk

2/27/2009

LSS Avionics Sparing Project Agenda

Honeywell

- Study Recommendations & Future Studies
  - Common Electronics between Altair & LSS
  - Common Layered Electronics Architecture for LSS Elements
- Dynamic Commissioning
- Abnormal Situation Management
- Wireless Equipment
- Conclusion/Final Thoughts
- Q&A

What is the Lunar Surface System?

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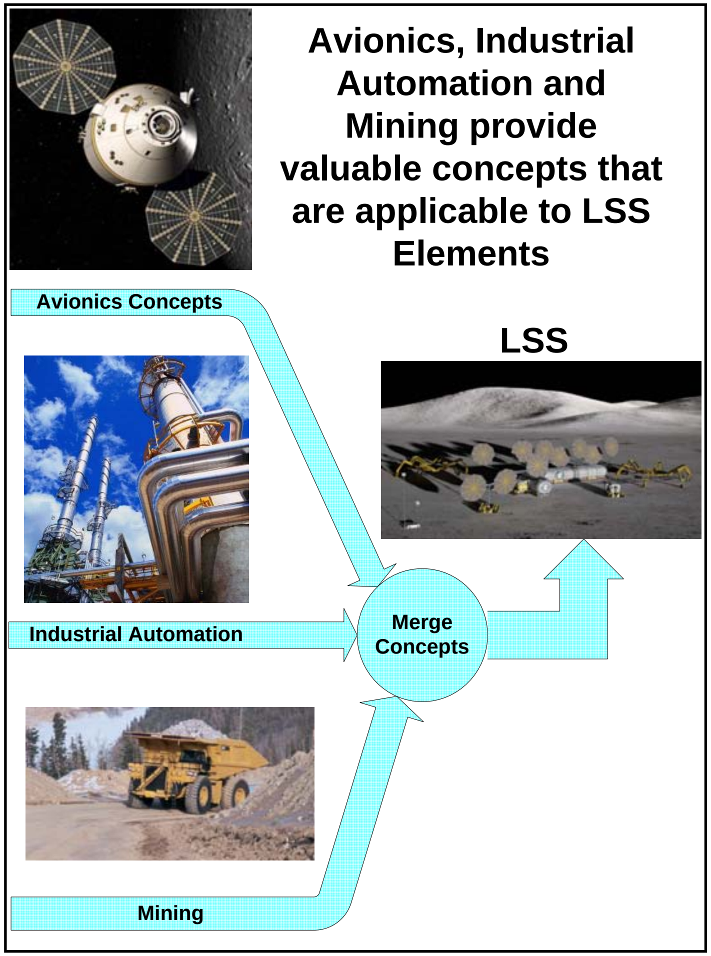
- Is it a vehicle?
- Is it a power generation facility?
- Is it a building?
- Is it a home?
- Is it a mining operation?
- Is it a refinery?
- Is it a research facility?



Yes, it is all of the above & more

LSS Avionics Study C

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Industrial Automation Building/Mining Concepts in a Standard Framework

- The objective of this stu ate innovative avionics architectures and sparin aximize commonality of avionics components ilitate in-situ repair s while minimizing mass of spares. Critical to sustainable avionics architecture are reductions ncluding indirect reductions via reductions in power, g, and maintenance spares.

Fewer Spares & Unique Spares

Multi Vehicle Equipment

- NASA state the following as Technical Cl the BAA:
  - Sev ly mass constrained
  - ployment to eventually coexist with subsequent generation e
  - networks are highly sparse by must still be robust

Integrated ISHM (Maintenance)

- Here are the re-stated design drivers:
  - Minimize Power
  - Minimize Weight
  - Enhance Commonality (Common Spares) for Reuse/Salvage
  - Address Maintenance of Equipment
  - Maintain Composability & Extensibility

6th Generation Avionics & Sensor Stds

Dynamic Commissioning

Wireless

Industry Standard Control Platform Architecture

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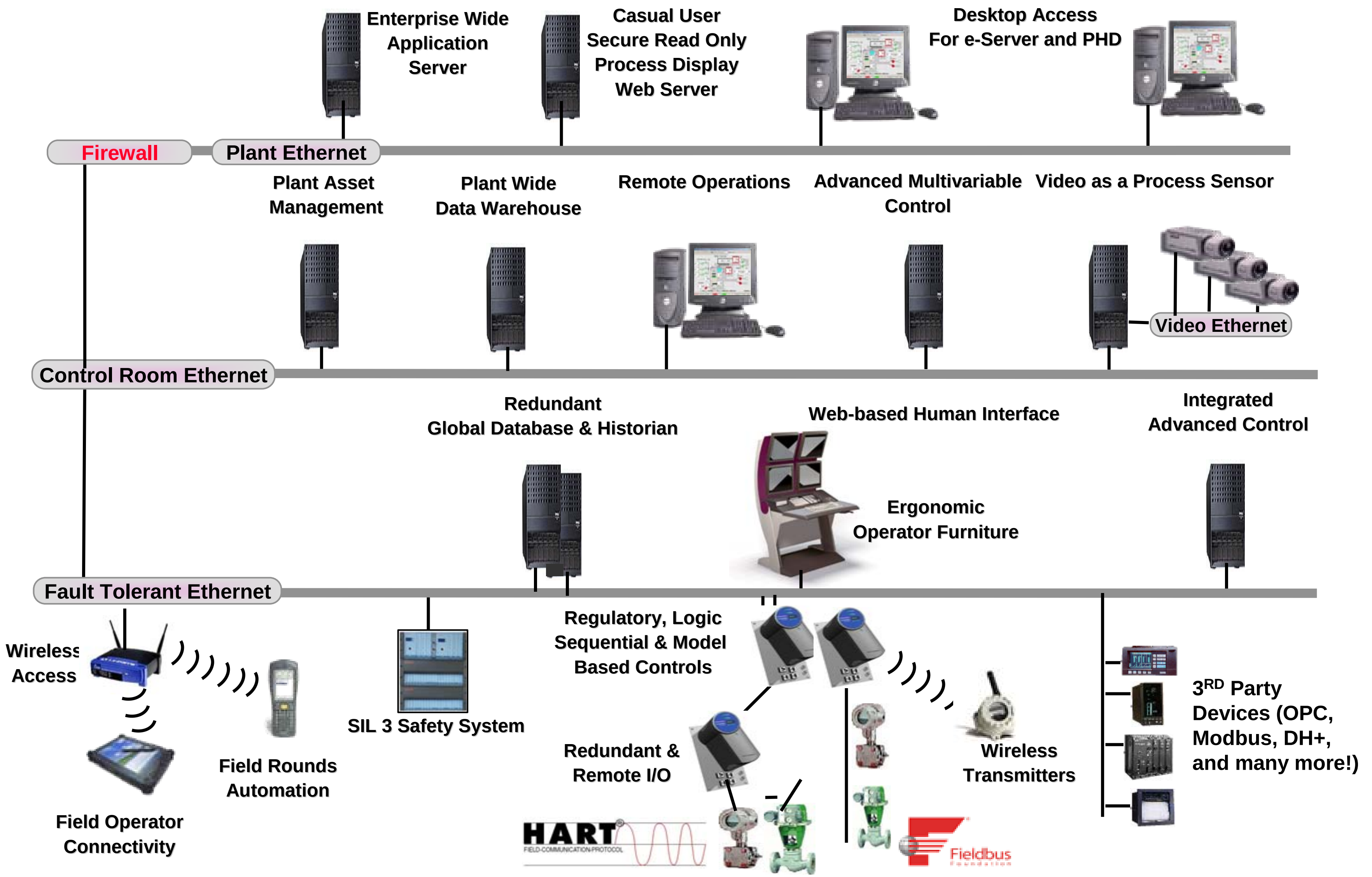

Based on Reference Model for Computer Integrated Manufacturing, ISBN 1-55617-225-7

Lunar Control Platform Architecture (Quick Look)

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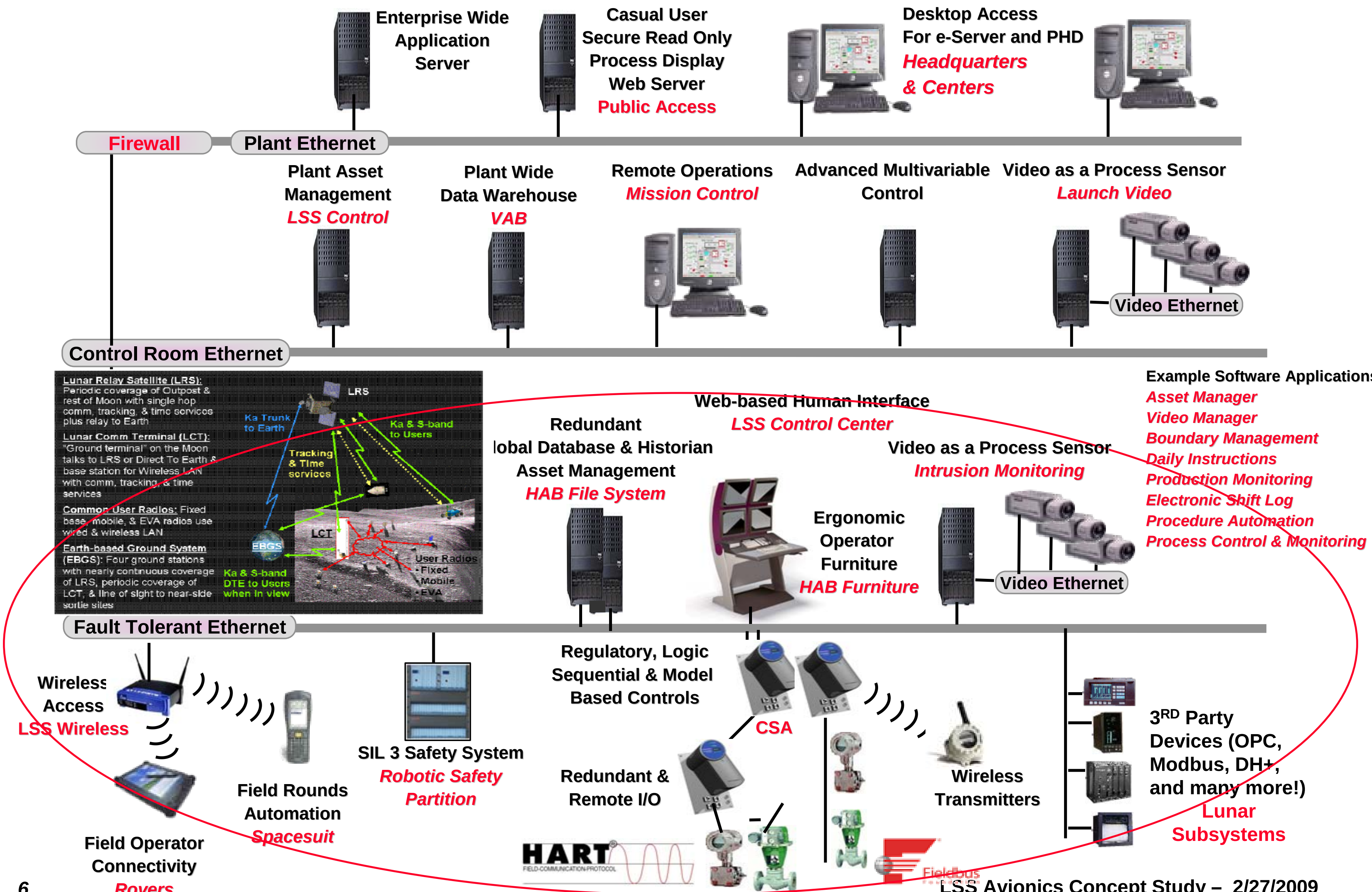

LSS Avionics Concept Study – 2/27/2009

Items in red could apply to NASA

Embedded System Comparisons

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- **Vetronics (Airplanes, Spacecraft, Armored Personnel Carriers, etc.)**
  - **Vehicle Specific Computing**
  - **I/O is built into the vehicle**
    - I/O distribution is part of the vehicle design
    - Sensors and actuators are limited to save weight and power
- **Process Control and other Terrestrial Systems**
  - **Architectures are hierarchical**
    - Regulatory control levels use standard purpose-built controllers (Level 1)
      - Often redundant to provide availability in case of communications failures
      - May be located remotely to reduce latency in control loops
    - Supervisory and enterprise levels use commercial information technology equipment (Level 2/3)
      - Conventional IT assets and protocols with modifications for real-time performance and reliability
  - **Applications are I/O intensive**
    - Some process applications have > 20,000 sensors/actuators
      - Sensors and actuators may be distributed over several miles
    - I/O usually is wired directly to controllers ("home run" wiring)
    - Newer equipment uses multi-drop buses for economy and ease of commissioning
      - Based on standard protocols such as Foundation Fieldbus, Profibus, LONworks, some Modbus
  - **I/O is commissioned in the field**
    - Older equipment requires manual configuration
      - Device addresses, data ranges and register assignments are manually set during installation
    - Newer equipment provides automatic discovery to minimize field labor
      - Device characteristics are sent by the device on connection
      - Device addresses are dynamically assigned by controllers
- **Lunar Surface System**
  - **Computing & I/O architecture use vehicle assets to implement a terrestrial I/O architecture**

Successful Common Avionics & Core Software

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- **Components**
  - **Chassis (3 Sizes)**
  - **Power Supply**
  - **Processor Module**
  - **Generic IOM (Reconfigurable)**
  - **Custom IOM (Unique IO for Vehicle)**
  - **Network Interface**
  - **Database Module (File System)**
  - **Display Units**
    - Smart Display Heads
    - Dumb Display Heads
  - **Radio Cabinet**
  - **Actuator IO Module**
  - **Flight by Wire Module (FBW)**

- **Vehicle (9 Total)**
  - **Helicopter**
  - **Regional Jets (2)**
  - **Business Jets**
    - European (3)
    - US
      - 3 Manufacturers
      - 4 Planes

- **Vehicle Unique Features Handled by**
  - **Custom IO Card**
  - **Software Applications**

Successful Commonality across Multiple Vehicles

Computing Commonality & Wireless Technology

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Designates initial industries of application

Industries	Wireless Applications: people / asset tracking	safety shower monitoring	equipment health monitoring	automated field operator rounds	emissions monitoring	leak detection	process optimization via more I/O	process diagnostics
Petrochemical refining	x	x	x	x	x	x	x	x
Pulp and paper manufacturing	x	x	x				x	
Continuous process industries	x	x	x		x	x	x	x
Power generation and distribution	x		x	x	x		x	x
Pharma industries		x	x			x	x	
Aluminum	x		x	x	x		x	x
Chemicals	x	x	x	x	x	x	x	x
Glass			x	x	x		x	
Metal casting	x		x				x	
Mining	x		x				x	
Steel	x		x	x	x		x	x

Successful Commonality across Multiple Industries

Top Recommendations/Future Studies

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Recommendations

1. Establish Programmatic Approach for Lunar Lander & LSS Electronics Commonality (Top Recommendation)
2. Establish a layered LSS Electronics Control Architecture across the vehicles
3. Establish Data Standards to allow data sharing & iinteroperability
4. IO Electronic Equipment/Power Control Integration

Suggested Future Studies

1. Sensor/Effector Type, Form Factor & Bus Standardization
2. LSS Equipment Health & Maintenance Approaches (especially in sensor/effector area)
3. Reconfigurable, Reusable LSS Software Architectures
4. Human Interface Standardization
5. Certification Standards
6. Altair and LSS Joint Avionics Development

Current Lander Electronic Commonality (Rec. 1)

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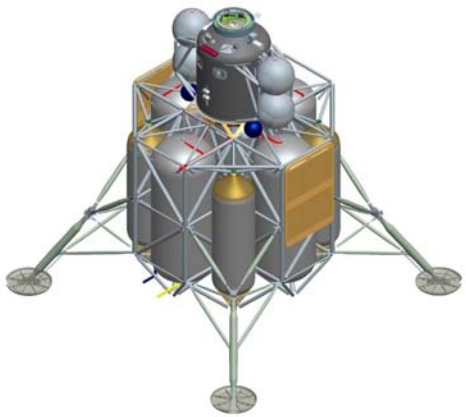
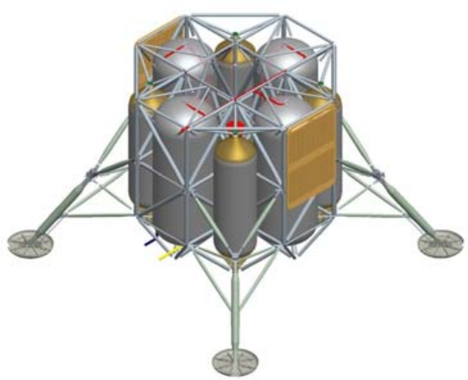


Crewed Lander



Cargo Lander

Existing Common Electronics Boundary

Extend Lander Electronics Commonality to LSS (Rec. 1)

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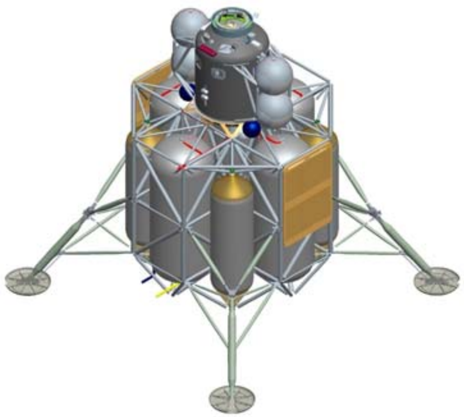
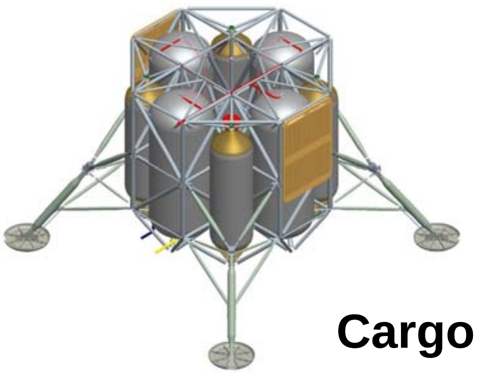
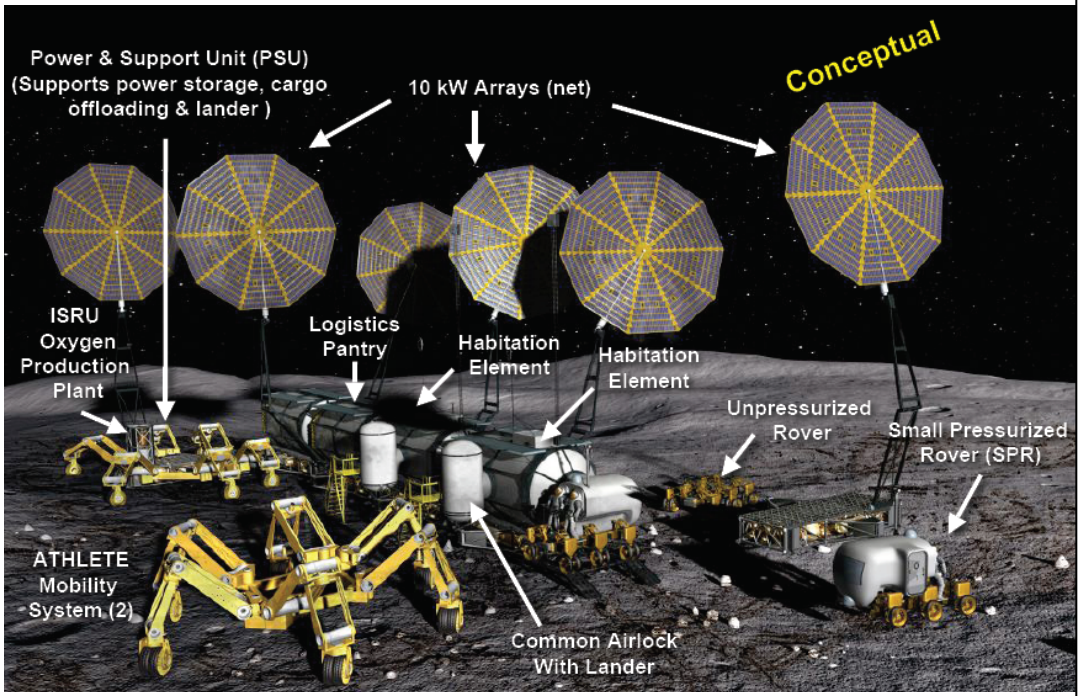


Crewed Lander



Cargo Lander



Proposed Common Electronics Boundary

Common Electronics across Lunar Entities

Why Lander/LSS Electronics Commonality?

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- **12 Lander Missions (2X Min. Configuration)**
  - 6 Cargo Missions (138 Kg of Avionics per vehicle)
  - 6 Crewed Missions (69 Kg of Avionics per vehicle assuming ½ Salvaged)
  - Total 1242 Kg of Avionics
- **LSS Buildup**
  - Habitat ~ 138 Kg of Avionics (~ Complexity of Lander)
  - Each of 12 Vehicles ~ 69 Kg of Avionics (1/2 Complexity of Lander) 12*69 = 828 Kg
  - Total ~ 966 Kg of Avionics
  - Leaves 276 Kg of Spare Avionics Weight

Saves transporting 1242 Kg of Avionics to the Moon
& procurement cost of extra LSS Electronics
& reduces number of unique spares and spares weight.
Requires coordination & different program approach

Implications of Common Electronics

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- Lander Electronic Equipment and LSS Electronic Equipment are largely common
- Programs needs to be structured to make this possible
  - Programs that design equipment for application across multiple vehicles work when ground rules and direction are established at program onset for all programs
  - Leader/follower programs with structured signoff to address programmatic issues work
    - Structure procurement to allow/enforce commonality between programs across vehicles with defined roles and responsibilities
    - Same requirements lead to different implementations without constant significant effort to bring implementations together
    - Put significant effort into keep things the same or procure the same parts for all vehicles

Commonality works with alignment of economic interests.

Layered Electronics Architecture (Rec.2)

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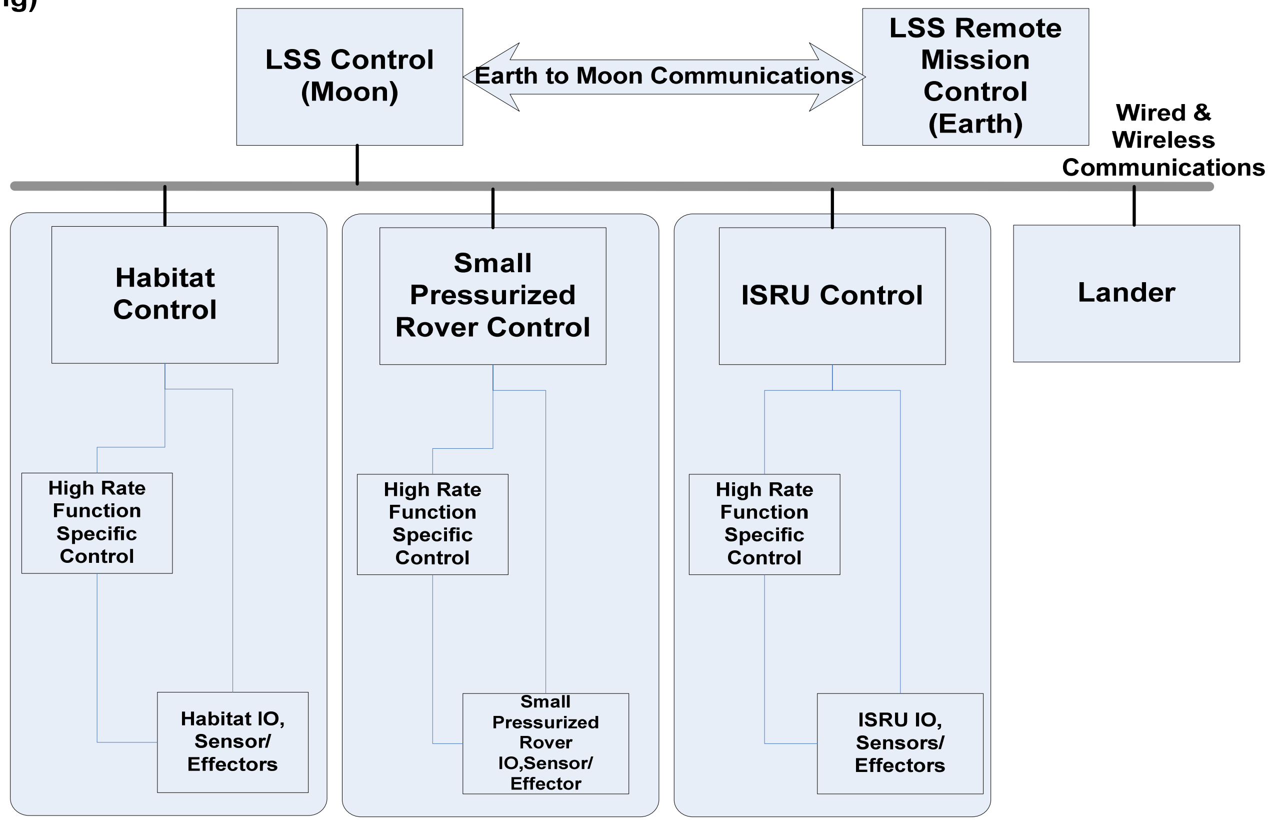
LSS Electronics Control Architecture Levels

Level 3 (High Level Planning)
- Production Mgmt
- Maintenance Mgmt
- Resource Mgmt
- Mission Planning

Level 2 (Vehicle Control)
- Sequencing
- Directing
- Coordinating
- Health Status
- Environmental Control

Level 1 (Basic Control)
- Power
- Movement
- Crew Interface

Standard Components
- Std Sensors/Effectors
- Data Concentrators
- Local Controllers
- Supervisor Controller/ Safety System
- Data Buses/Data Communications
- Functions
- Software
- File System



Enabled by standard functionality at each level with communications enabled by data standards

Habitat has layers 1,2,3 . Vehicles having layers 1 & 2.

Layered Electronic Architecture Components (Rec. 2)

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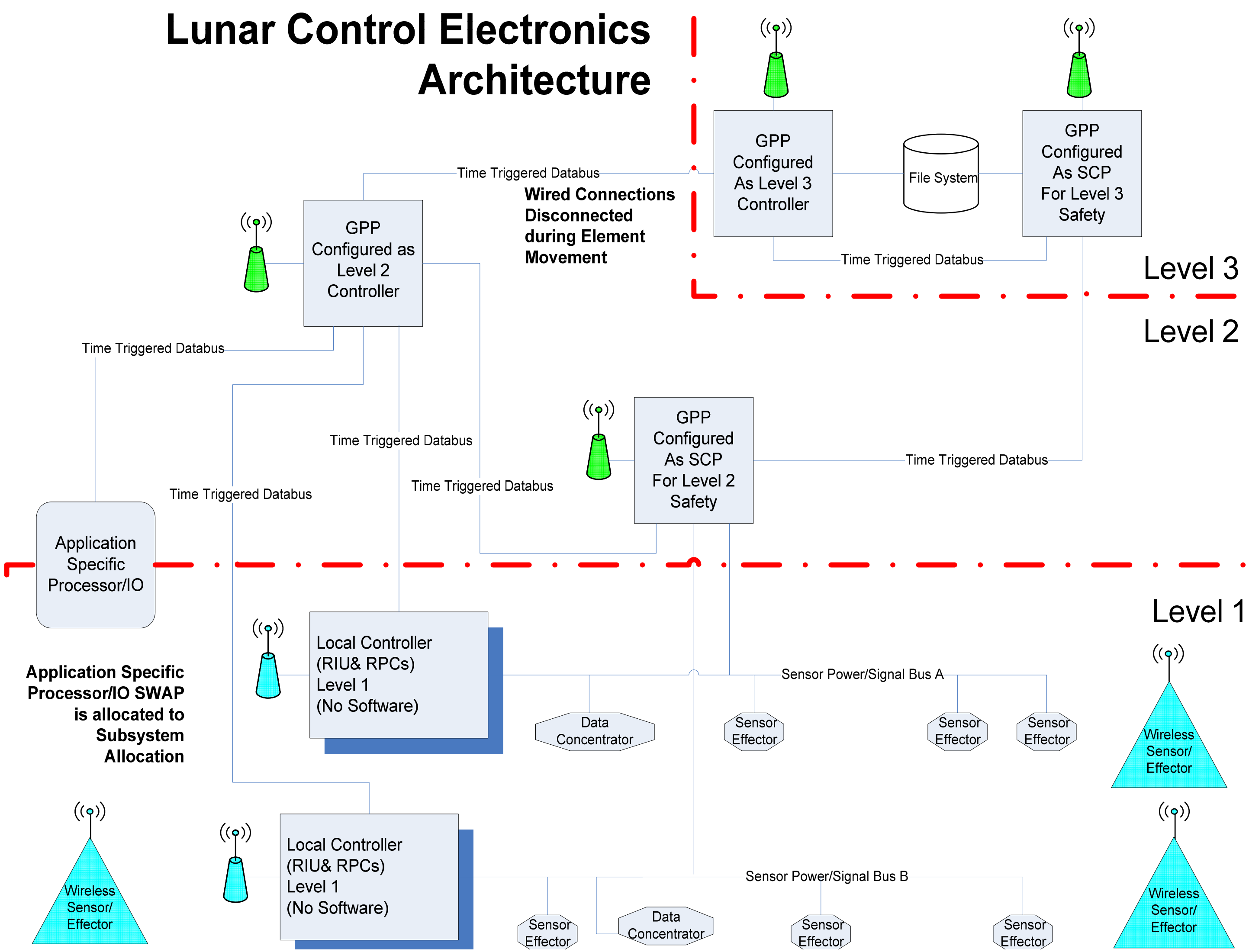

Functions (Space & Industrial Automation Superset)

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Level 3 Functions (Planning)

Automation Control Functions

- Production Mgmt
- Daily Instructions
- Procedure Automation
- Production Monitoring
- Boundary Management
- Electronic Shift Log
- Maintenance Mgmt
- Procedure Automation
- Resource Mgmt
- Asset Manager
- Alarm System Analysis & Awareness
- Video Manager

LSS Functions

- Crew Health Monitoring and Medical Systems
- External Environment Monitoring and Protection
- Mission Planning and Operations
- Prognostics, Maintenance and Logistics Mgmt

Level 2 Functions (Vehicle Control)

Automation Control Functions

- Vehicle Control
- Sequencing
- Directing
- Coordinating
- Health Status
- Process Control & Monitoring

LSS Functions

- Command and Data Handling
- Communications & Tracking
- Crew Health Monitoring and Medical Systems
- Environmental Control and Life Support
- External Environment Monitoring and Protection
- Guidance Navigation and Control
- Remote and Autonomous Operation
- Surface Navigation
- Thermal Control
- Waste Management

Level 1 Functions (Basic)

Characteristics

- High Rate Closed Loop Control
- Standard IO/Power Control
- Standard Sensor/Effectors

LSS Functions

- Power
- Mobility
- Crew Interface
- Lighting (Part of ECLS)

Layers allowed for grasping project scope/relationships

Layered Electronics Architecture Findings

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Area	Recommendations	Impact
Sensor/Effector	Standardize Sensor/Effector	Fewer Spares (est. 80% Reduction in Sensor/Effector Spares)
Sensor/Effector Buses	Use Sensor Buses	Less Wire Weight (est. 1/3 reduction in Sensor/Effector Wiring)
Local Controller/Power Control	Non-Software Controller with 4-6 Card Types, power control & some flexible IO	Less Weight, Fewer Spares, Addresses Common Mode SW Faults & Exposure Time (est. 6-9 Kg reduction by 6-9 fewer unique cards)
Supervisor Controller/ Safety System	Create General Purpose Reconfigurable Processor for all vehicles	Less spares weight with 1 spare computer type, Lander Commonality Bonus
Databuses/Data Comm	Integrated Wired & Wireless	Flexibility vs Wire Weight vs Sensor Weight
Functions	Review Mining & Process Control Functions	Look for commonality between vehicles to reduce duplication
Software	Design Assurance Levels, Multiple SW Environments, Data Standards, Common Software	Reduced Cost, More Flexibility, Increased Safety
Architecture Capabilities	Implement basic and advanced architectural capabilities	Easier Upgrades, Maintenance, Safety

Advanced Capability – System Commissioning

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- **Adapts a system to a specific field environment**
  - **Installs and configures components to field constraints**
    - Installs sensors and actuators
    - Installs communications and power wiring
    - Sets computer parameters and drivers for field IO devices
    - Inventories devices and configures device addresses and parameters
    - Installs application software and tunes application parameters
  - **Tests system operation**
- **Typically the last step before a system is declared operational**
  - **Always performed in the field**
  - **Verifies the system meets user needs**
  - **Must be repeated if major system changes or upgrades occur**

Commissioning Activities Shift to the Field (Moon)

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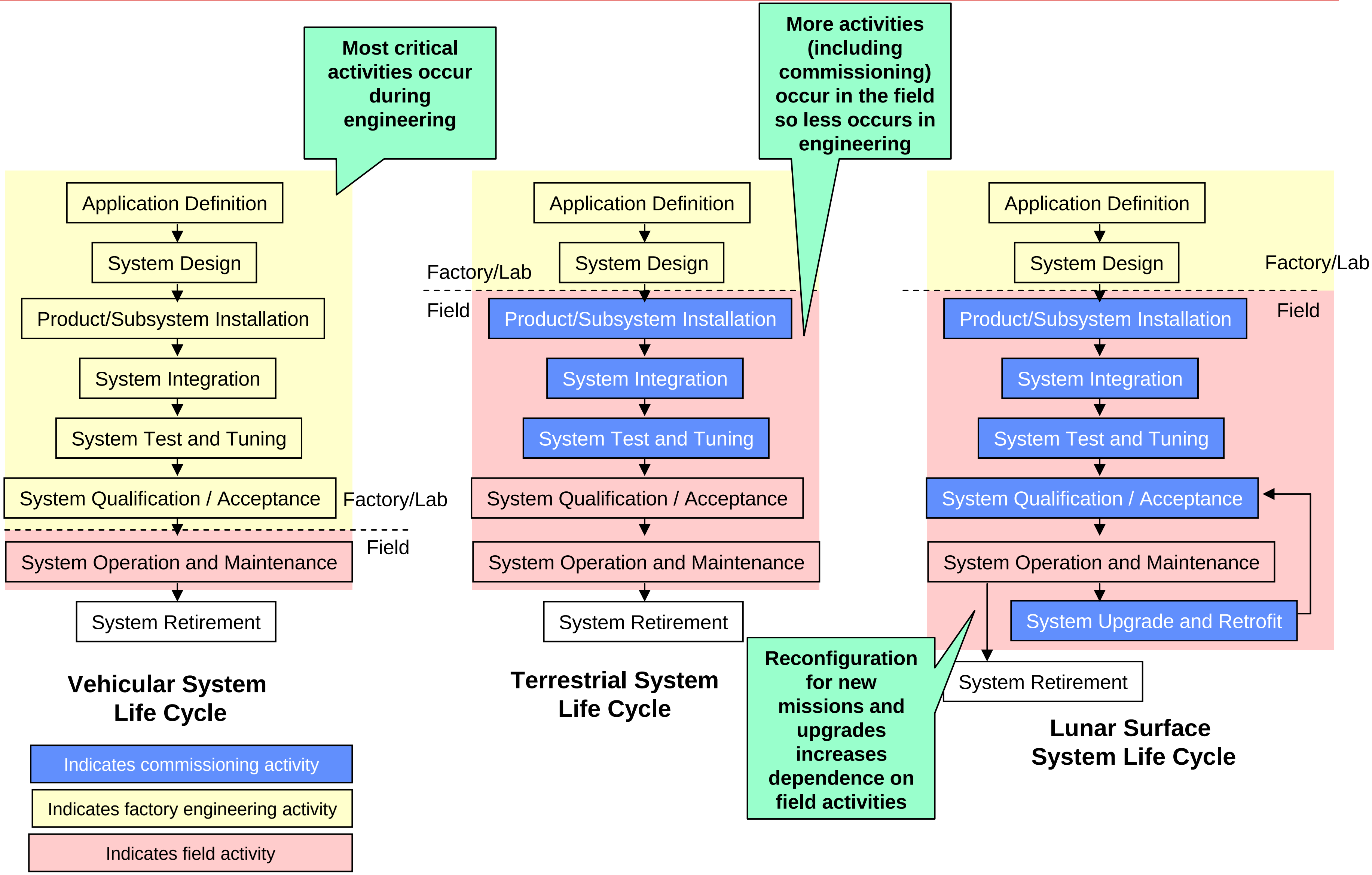

Advanced Capability – Dynamic Commissioning

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- **Extends conventional system commissioning to support evolving field operations in a remote environment**
  - **Provides flexibility to adapt to changing conditions**
    - Build-out of lunar habitations and communications
    - Mission evolution
  - **Uses standard and reusable components to minimize field configuration effort**
    - Standard computers for economy and interchangeability
    - Standard Multi-purpose I/O module architecture for flexibility
    - Standard sensors and actuators for simplicity and reuse
    - Prewired I/O to simplify hardware installation
    - Dynamic device discovery and configuration to minimize manual configuration of device addresses and parameters
    - Standard communications to minimize time spent in harsh environments
  - **Supports commissioning with software**
    - Unified database of process points to manage data aggregation and distribution
    - Automated discovery and provisioning software to eliminate manual data entry
    - Standardized software for data visualization and control

Abnormal Situation Management Consortium

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ChevronTexaco

ExxonMobil

Celanese

NOVA Chemicals®

ConocoPhillips

Shell

UCLA

TTS Performance Systems, Inc.

BAW Architecture

USER CENTERED DESIGN SERVICES
Achieving Excellence in Control Room Operations

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- **Charter:**
  - **Research the causes of abnormal situations and create technologies to address this problem to prevent loss of life, time and equipment**
- **Deliverables:**
  - **Technology, best practices, application knowledge, prototypes, metrics**
- **History:**
  - **Started in 1994**
  - **Co-funded by US Govt (NIST)**
  - **Budget: +$16M USD**
  - **Honeywell Sponsored**
  - **Expanding membership**
  - **www.asmconsortium.net**

7 Practice Areas to Prevent Accidents

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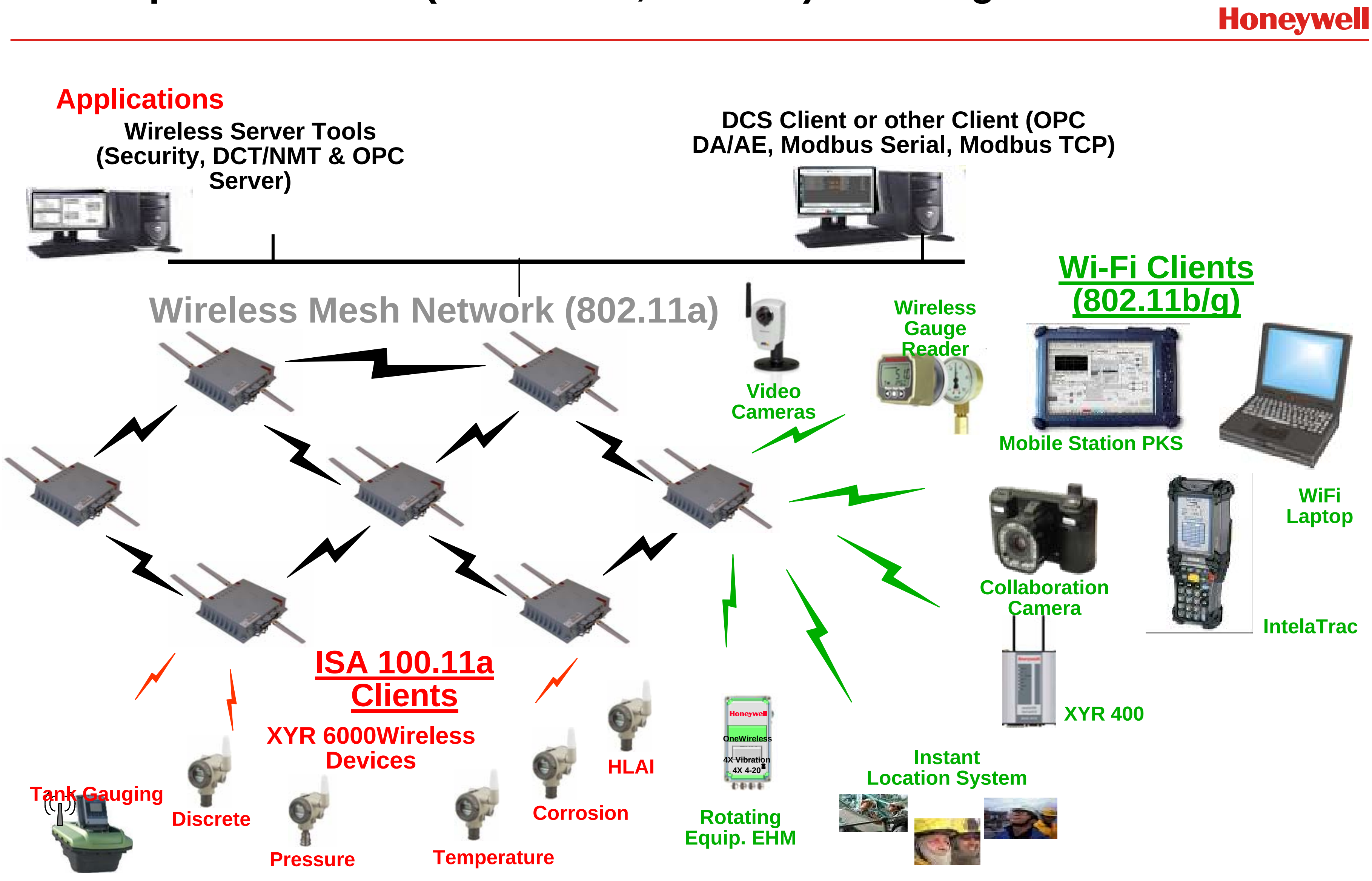
- **Understanding Abnormal Situations**
- **Organizational Roles, Responsibilities and Work Processes**
- **Knowledge & Skill Development**
- **Communications**
- **Procedures**
- **Work Environment**
- **Process Monitoring Control & Support Applications**

"In systems where a high degree of hardware redundancy minimizes the consequences of single component failures, human errors may comprise over 90% of the system failure probability."

"A Manager's Guide to Reducing Human Errors" API Publication 770, March 2001

Four Open Networks (3 Wireless, 1 Wired) Tied Together



Wireless Sensors in a Refinery (Find the LSS Parallels)

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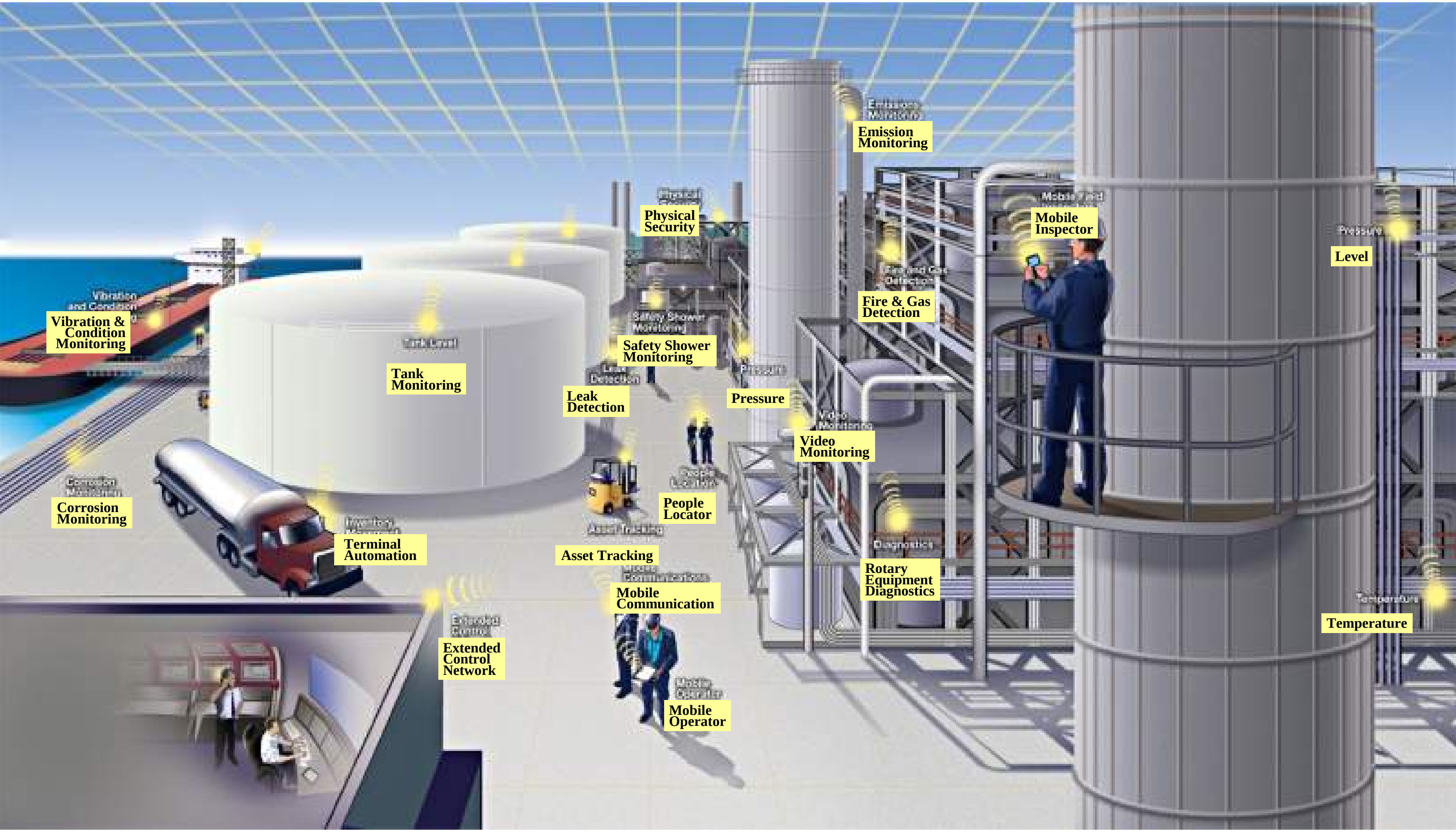

DOE Contract: Wireless and Sensing Solutions for Improved Industrial Efficiency
Honeywell Project: Wireless Networks for Secure Industrial Applications

Conclusions
&
Final Thoughts

LOCKHEED MARTIN

Honeywell

Conclusions

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Aerospace

Building Automation

Industrial Automation

Mining

Mesh, Fuse, Merge, Concepts

"Spacize" Implementation

LSS Electronics System

The real strength came from combining concepts and capturing lessons learned from multiple industries --

No one has the market cornered on good ideas.

Final Thoughts

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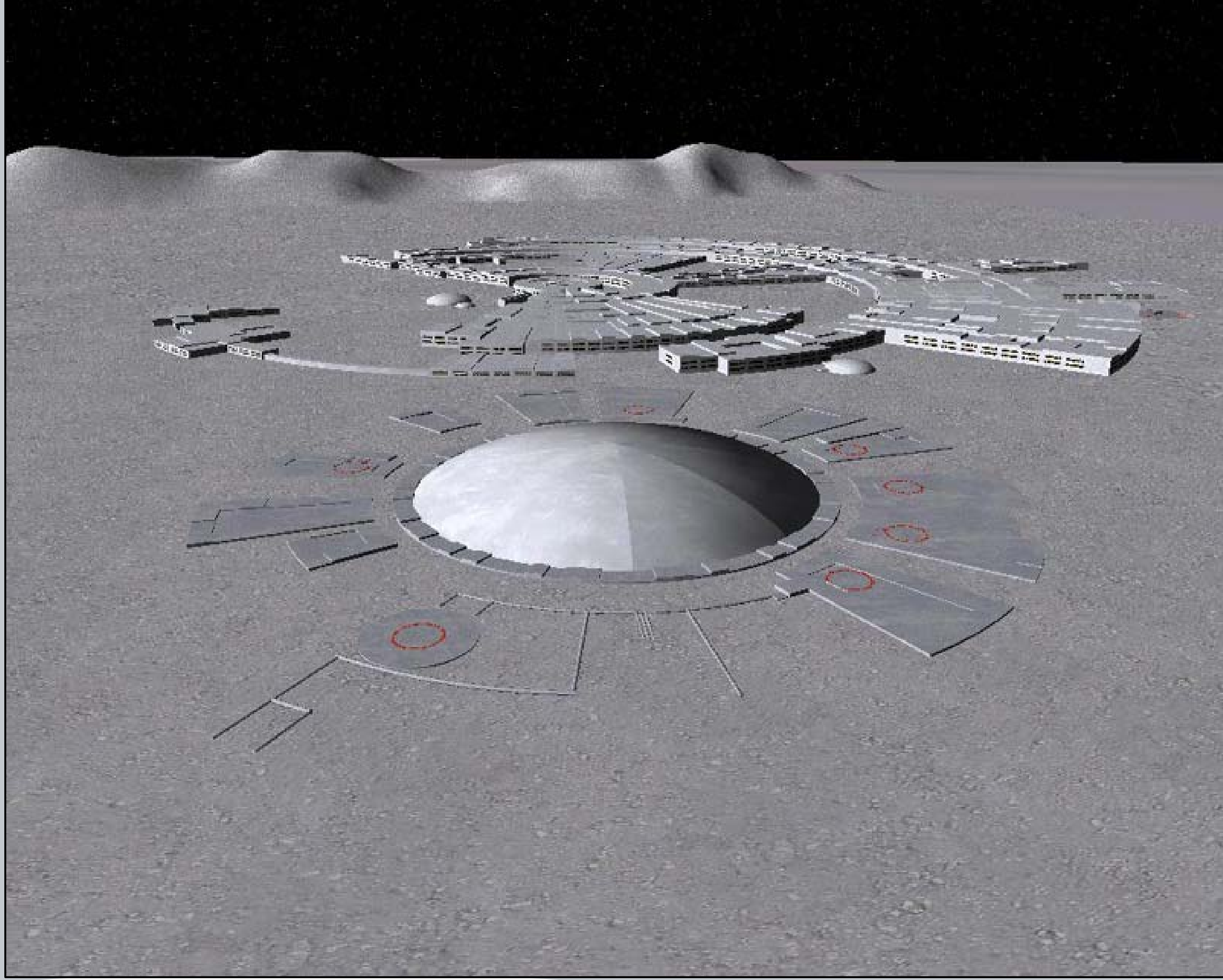
- **Thought 1**
  - **Superset of Aerospace, Building Automation, Industrial Automation and Mining Operation concepts and existing technologies can be applied so there are no major technical gaps in the computing/electronics area.**
  - **Solutions exist “spacizing” process required**

- **Thought 2**
  - **Commercial programs has succeeded with this amount of commonality when structured to do so.**
  - **Programmatics of running a government program with the recommended level of commonality will be challenge to the current way of doing business.**
  - **This programmatic roadblock seems like one we need to remove if not for this concept then for the next commonality idea (e.g. Software).**

Questions

Backup



Purdue Reference Model

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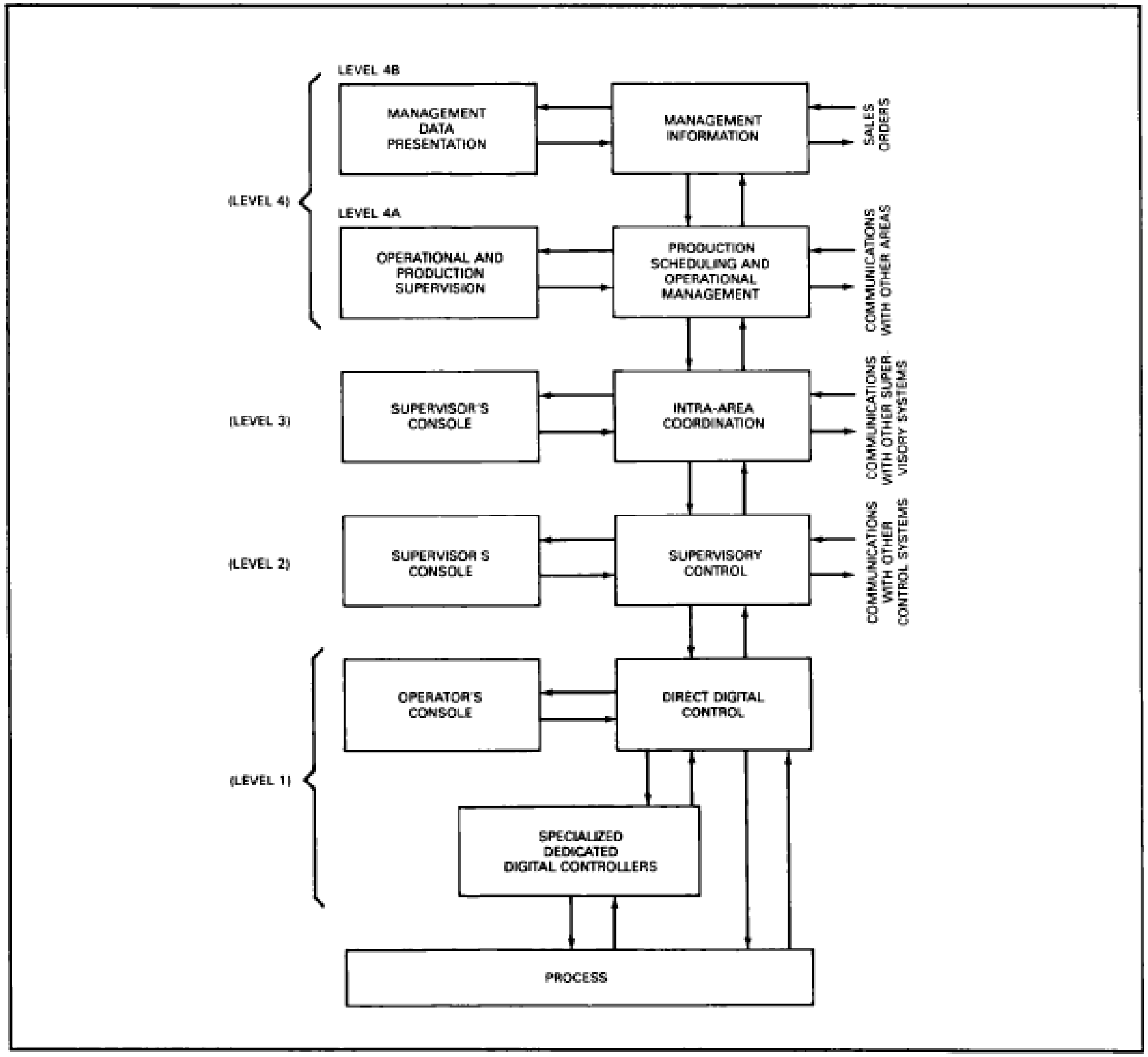

Figure 3-1 Assumed functional hierarchical computer control structure for an industrial plant (continuous process such as petrochemicals).

A Reference Model for Computer Integrated Manufacturing, ISBN 1-55617-225-7

Purdue Model Responsibility

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IPW LEVEL NOTATION	WG1 LEVEL	HIERARCHY	CONTROL	RESPONSIBILITY	BASIC FUNCTIONS	
NULL	6	ENTERPRISE	CORPORATE MANAGEMENT	Achieving the mission of the enterprise and managing the corporate	— CORPORATE MANAGEMENT — FINANCE — MARKETING & SALES — RESEARCH & DEVELOPMENT	CONSIDERED AN EXTERNAL ENTITY IN THE IPW WORK
4	5	FACILITY/ PLANT	PLANNING PRODUCTION	Implementation of the enterprise functions, and planning and scheduling the production	— PRODUCT DESIGN & PRODUCTION ENGINEERING — PRODUCTION MANAGEMENT (Upper Level) — PROCUREMENT (Upper Level) — RESOURCES MANAGEMENT (Upper Level) — MAINTENANCE MANAGEMENT (Upper Level)	
3	4	SECTION/ AREA	ALLOCATING AND SUPERVISING MATERIALS & RESOURCES	Coordinate the production and supporting the jobs and obtaining and allocating resources to the jobs	— PRODUCTION MANAGEMENT (Lower Level) — PROCUREMENT (Lower Level) — RESOURCES MANAGEMENT (Lower Level) — MAINTENANCE MANAGEMENT (Lower Level) — SHIPPING — WASTE MATERIAL TREATMENT	
2	3	CELL	COORDINATE MULTIPLE MACHINES AND OPERATIONS	Sequencing and supervising the jobs at the shop floor, and supervising various supporting services	— SHOP FLOOR PRODUCTION (Cell Level)	
1	2	STATION	COMMAND MACHINE SEQUENCES AND MOTION	Directing and coordinating the activity of the shop floor equipments	— SHOP FLOOR PRODUCTION (Station Level)	
0	1	EQUIPMENT	ACTIVATE SEQUENCES AND MOTION	Realization of commands to the shop floor equipments	— SHOP FLOOR PRODUCTION (Equipment Level)	NOT INCLUDED BECAUSE OF WIDE DIFFERENCES OF EQUIPMENT AND FUNCTIONS BETWEEN DIFFERENT INDUSTRIES

Figure 3-4 Factory automation model.

A Reference Model for Computer Integrated Manufacturing, ISBN 1-55617-225-7

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