



# Holonic Manufacturing Systems

## Phase 1 and Phase 2



Edwin van Leeuwen  
Chairman, HMS Board



## Presentation Overview

- ◆ HMS Project
- ◆ Holonic Systems
- ◆ Industrial Testbeds
- ◆ HMS Phase 2



# Basis of Holonic Systems

## ◆ Arthur Koestler

- *The Ghost in the Machine*, 1969
- Modeling of biological and social systems

## ◆ Holon

- Greek word “holos” meaning whole
- Suffix “on” denoting a particle
- Similar to AGENTS but always cooperative
- Self-contained unit capable of functioning independently but dependent on other units

## ◆ Holonic System

- Open modular
- Decision-making autonomy
- Cooperation by message passing and negotiation

Autonomy



Cooperativeness



## Benefits of HMS

- ◆ Robustness to disturbances
- ◆ Human integration
- ◆ Availability
- ◆ Flexibility
- ◆ Scalability
- ◆ Coordination of distributed decisions
  - Different times, locations, contexts, people
- ◆ Ideally suited for manufacturing and supply chain enterprises
  - Adaptive and distributed
  - Can add intelligence with soft computing technologies



## HMS Objectives

- ◆ Develop, market and support HMS **compatible** devices, components, subsystems and support tools
- ◆ Design, implement, deploy and support HMS in **industrial** applications
- ◆ Increase the **understanding, systematization, and acceptance** of HMS concepts
- ◆ Support the development of **international standards** which contribute to the achievement of HMS goals



# HMS Project

- **5 Regions**

Australia, Canada, EU, Japan, USA

- ◆ **30 Organizations**

- **Industry**

ATOS, BHP Billiton, DaimlerChrysler, Fanuc, Rockwell Automation,  
Toshiba, Yaskawa Electric

- **R&D Laboratories**

CSIRO, Fraunhofer IPA, NRC Canada, Profactor, VTT Automation

- **Universities**

Calgary, Connecticut, Hannover, Keele, KU Leuven, Osaka, SFU, Tokyo,  
Vanderbilt

- ◆ **Invested US\$50,000,000**

- Feasibility study 1991-93
- Phase 1: 7 work packages 1995-00
- Phase 2 : 4 work packages 2001-04

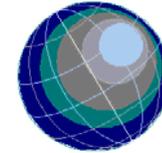


HMS Phase I and II



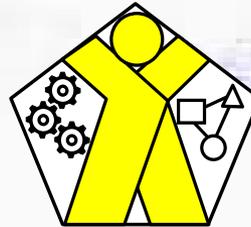
Engineering

Operation



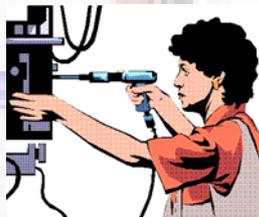
Distributed Production Management

Education & Training

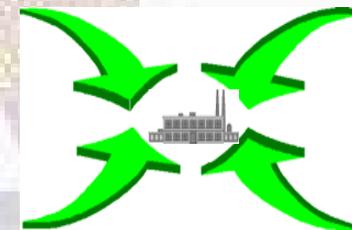


Business Planning & Operation

Manual Work Integration



Supply-Chain Management



Business & Enterprise Integration



# Holonic Manufacturing Systems

Presentation to ISC Board, May, 2002  
Okinawa, Japan



**Project 95003**

**Effective Date of Commencement  
of the HMS Project: February 15, 1996  
Phase I Termination: October 15, 2000  
Phase II Commencement: October 16, 2000**



## HMS Vision

### *Manufacturing Challenge*



- Rapid delivery of



- customized Products in



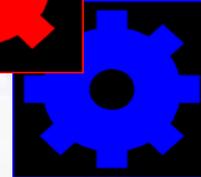
- competitive global markets

### *Required Characteristics*

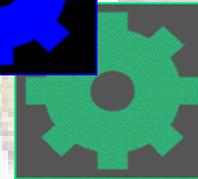
**Flexibility**



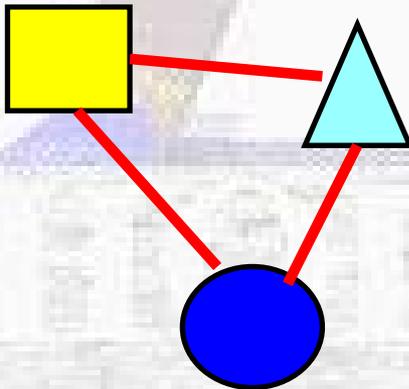
**Agility**



**Robustness**



### *The Solution:*



**Autonomous  
Cooperative  
Modules**

**Holons**



## HMS Mission

### Basic Technology and Organisation for Worldwide Goals:



→ **HMS Compatible Devices and Systems**



→ **HMS in End-user Applications**



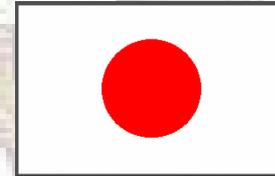
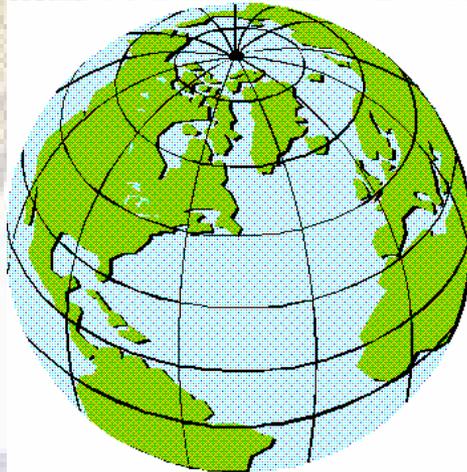
→ **Understanding & Systematization of HMS**



→ **International Standards**



# The Coordinating Partners of HMS



**TOSHIBA**



**Rockwell  
Automation**

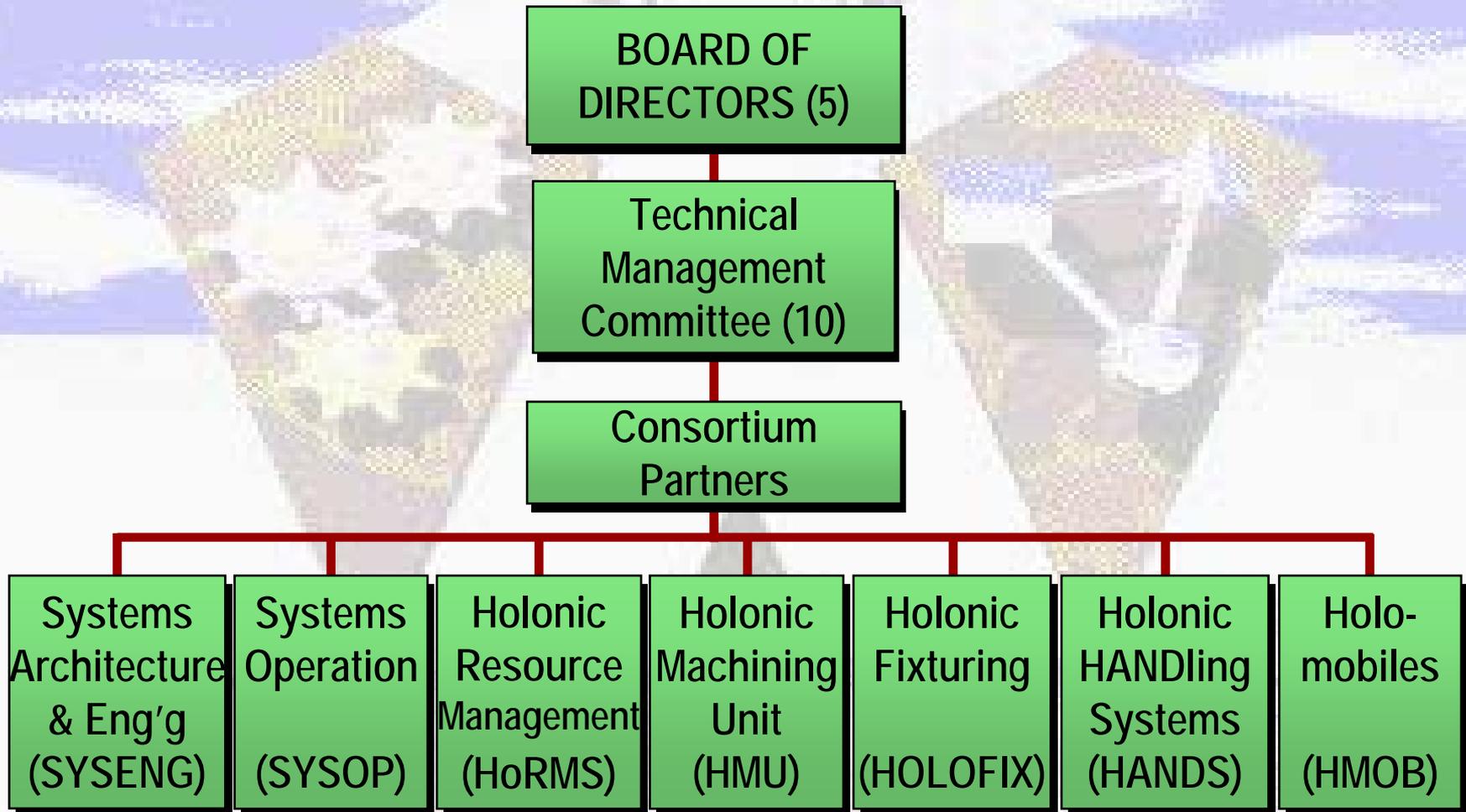


**International  
Coordinating  
Partner**



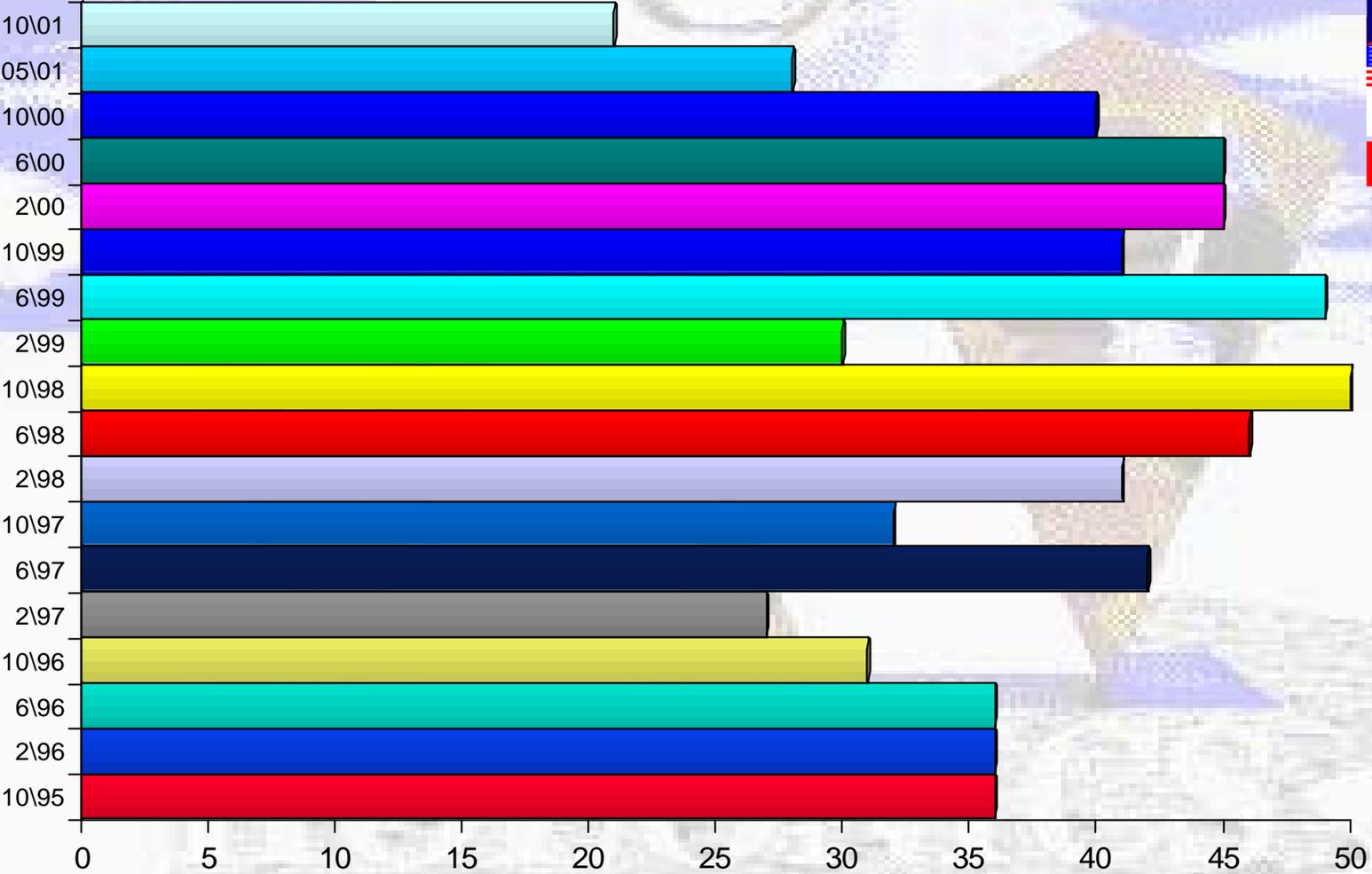


## HMS Management Structure Phase I





# HMS Meeting Attendance



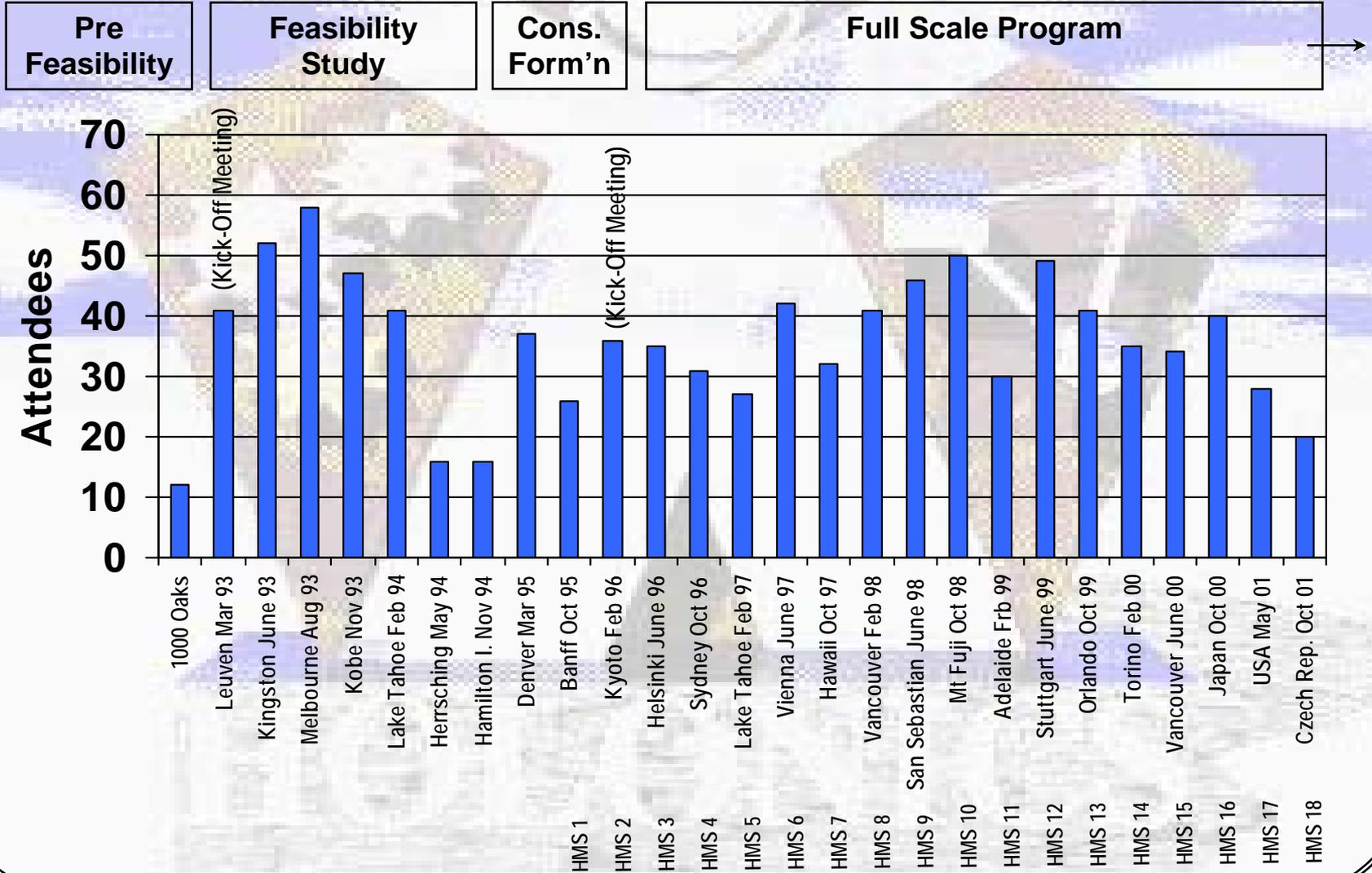


## Composition of Consortium Contributions (Man Months) Phase I

Region	Aust	Canada	EU	Japan	USA	Total	%
End User	110	80	184	169	-	543	23.85%
System Integrators	-	-	107	-	-	107	4.70%
Vendors	-	-	61	351	24	436	19.15%
Research Institutes	211	-	345	-	-	556	24.42%
Academic Partners	124	122	46	270	73	635	27.89%
<b>Total</b>	445	202	743	790	97	2277	100%
<b>%</b>	19.54%	8.87%	32.63%	34.69%	4.26%	100%	

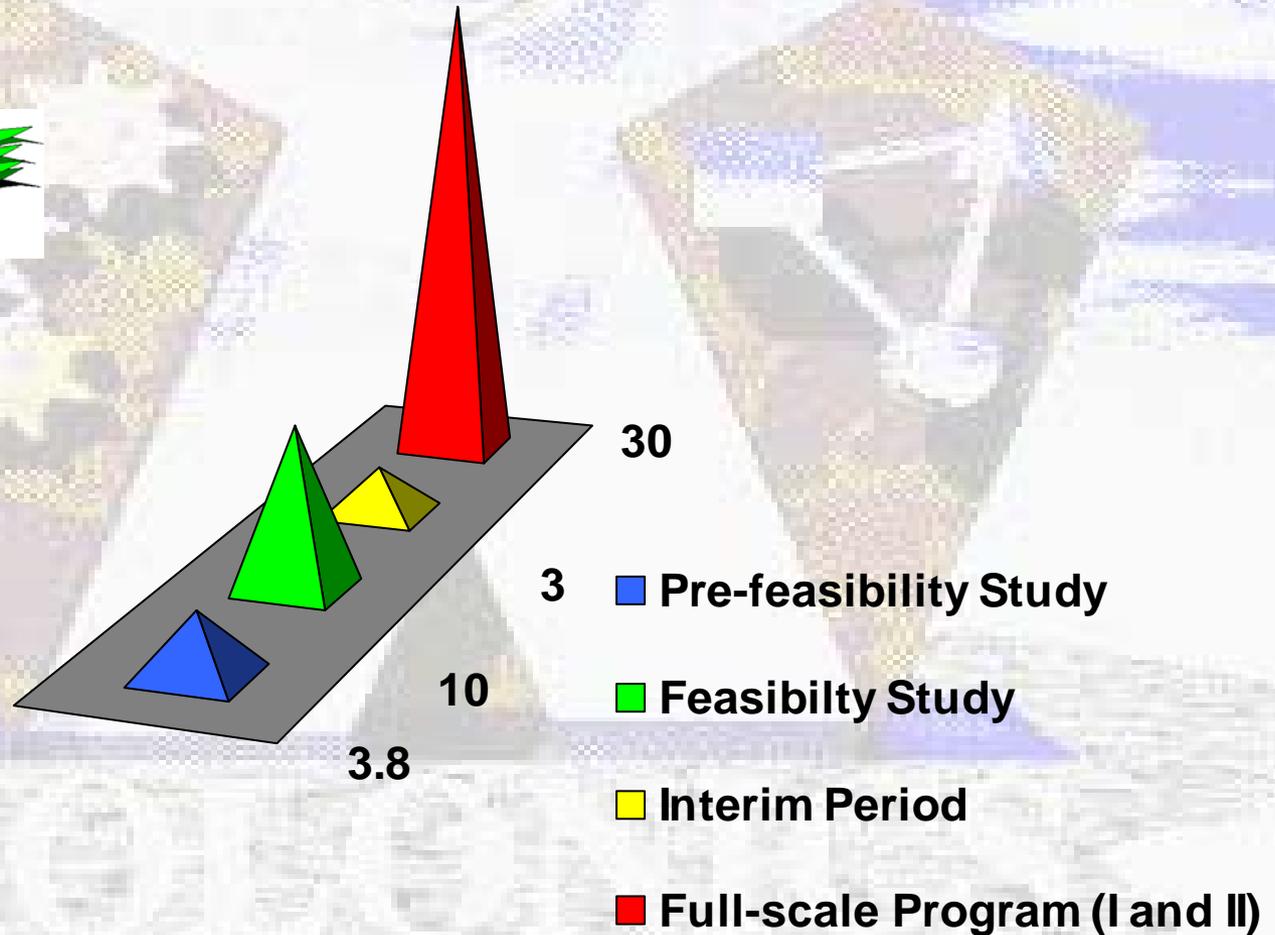


# International Meeting Attendance





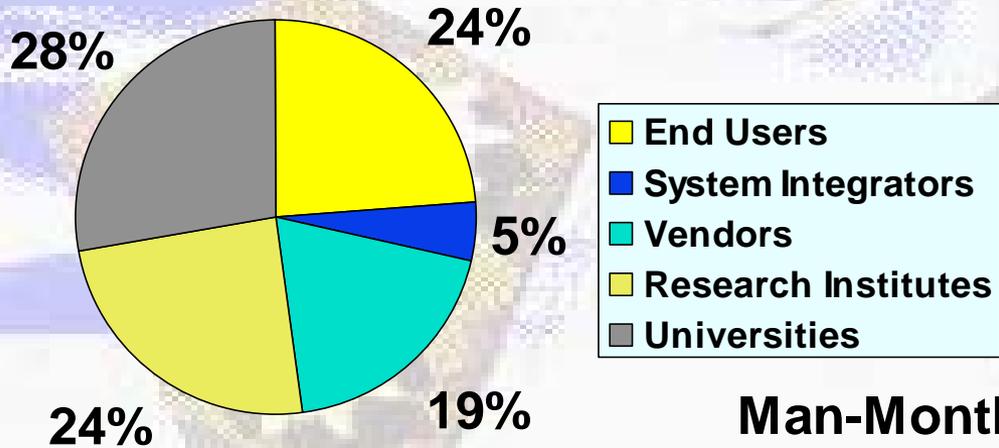
# Investment by Partners in million US\$ Phase I



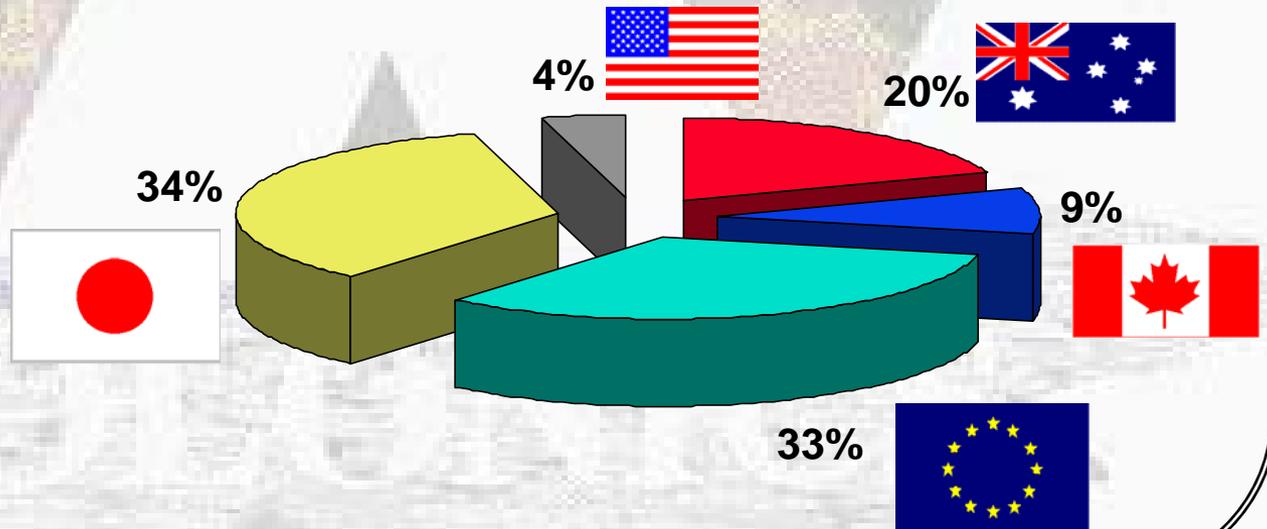


# HMS Regional Contributions

## Man-Month by Organisation type

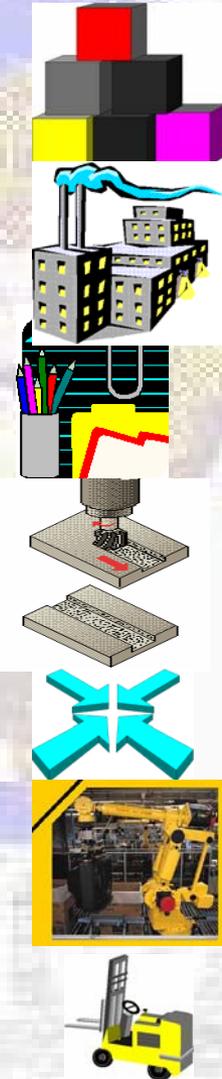


## Man-Month by Region





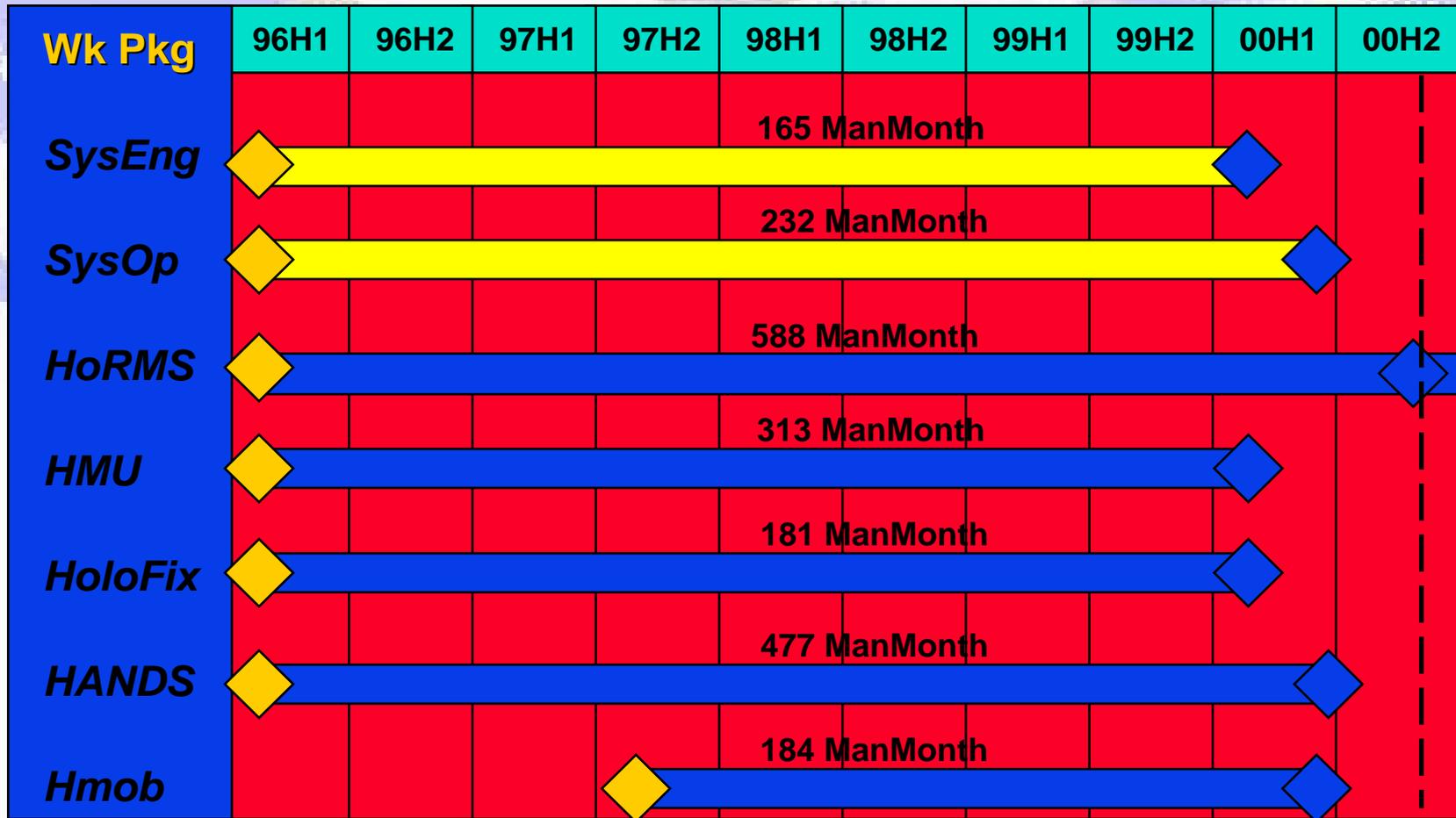
## HMS Work Packages



- **WP1 System Architecture and Engineering**
- **WP2 System Operation**
- **WP3 Holonic Resource Management**
- **WP4 Holonic Machining Unit**
- **WP5 Holonic Fixturing Station**
- **WP6 Holonic Handling System**
- **WP7 Holomobiles**



# HMS - Work Package Duration and Effort



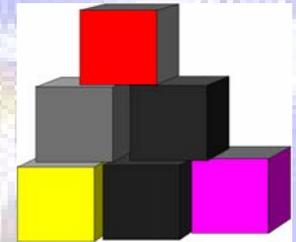


## HMS - Major Accomplishments

**WP1/1: HMS Architecture Model**

**WP1/2: IEC6-1499 function block Holonic elements**

[http: www.holobloc.com](http://www.holobloc.com)



**WP2/1: Reliable communication protocol specification**

**WP2/2: Knowledge representation and interpretation for resource allocation**



**WP3/1: Part-oriented control models of engine manufacturing systems**

**WP3/2: Simulation study of holonic maintenance scheduling in steel production**



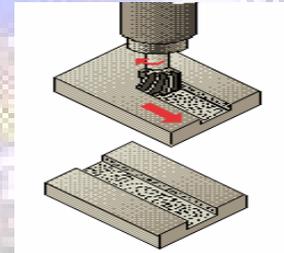


## HMS - Major Accomplishments

**WP4/1: Control Architecture of Machine Tool Holon**

**WP4/2: System architecture of manufacturing preparation system**

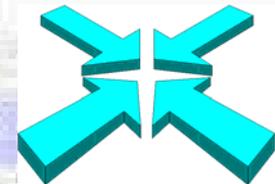
**WP4/3: Holonic process planning**



**WP5/1: Cooperation algorithm for workpiece identification - development of sensor holon**

**WP5/2: Algorithm for workpiece manipulation system for fixturing**

**WP5/3: Design of the Holonic Fixturing Station**





HMS - Major Accomplishments

**WP6/1: Motion control methods for co-operating robots**



**WP6/2: Communication interface and protocol of sensor holons**

**WP7/1: Simulations: Holonic Motor Block Assembly Line; Holonic AGV Material Flow for Engine Assembly Line**

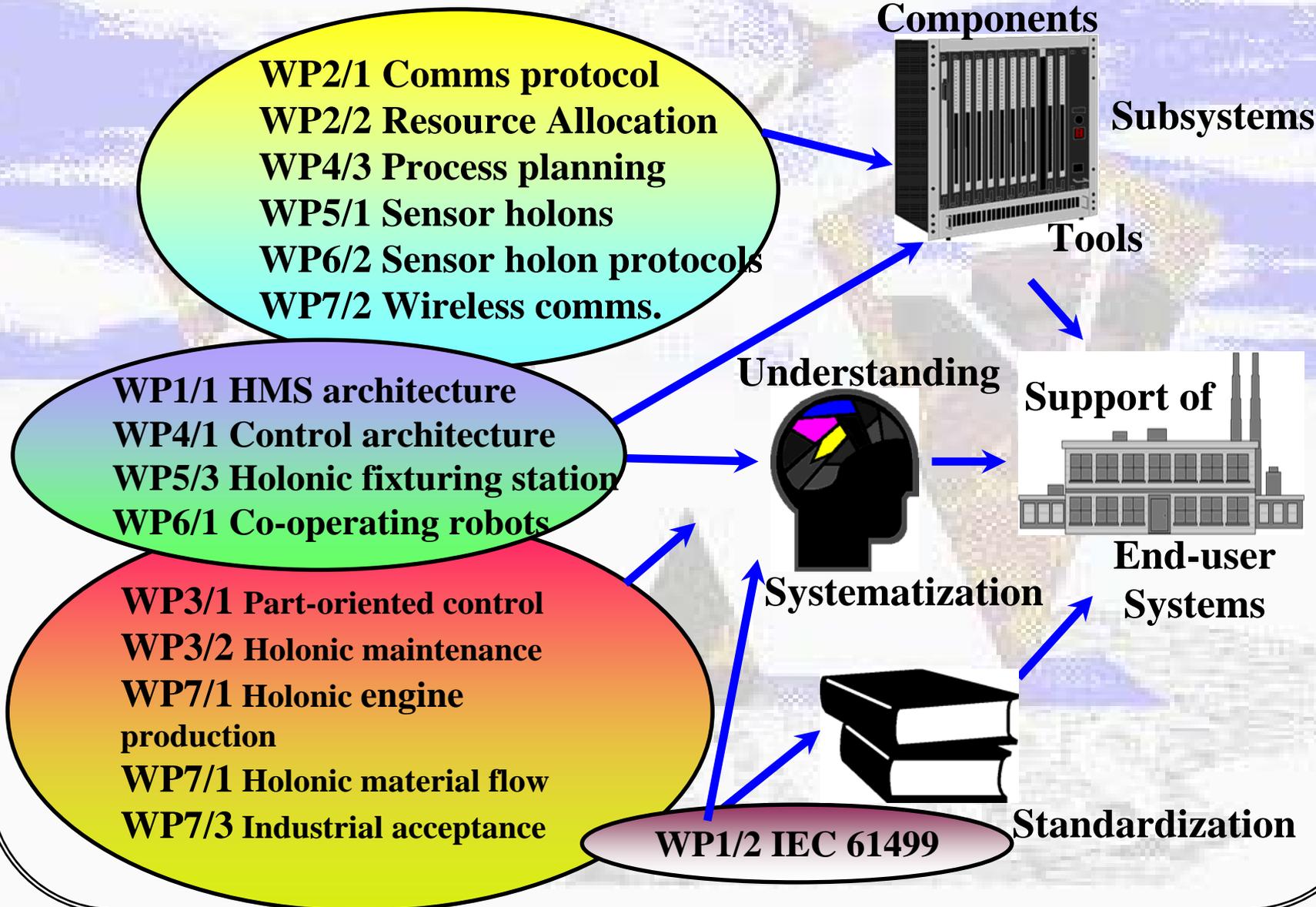


**WP7/2: Wireless Communication Modules**

**WP7/3: Acceptance of Holonic line configuration proposal by Daimler-Chrysler**



# ACCOMPLISHMENTS TO HMS GOALS





## Phase 1 Work Packages

- ◆ WP1 Systems Architecture and Engineering
- ◆ WP2 Systems Operation
- ◆ WP3 Holonic Resource Management
- ◆ WP4 Holonic Manufacturing Unit
- ◆ WP5 Holonic Fixturing
- ◆ WP6 Holonic Handling Systems
- ◆ WP7 Holomobiles

Completed February 2000

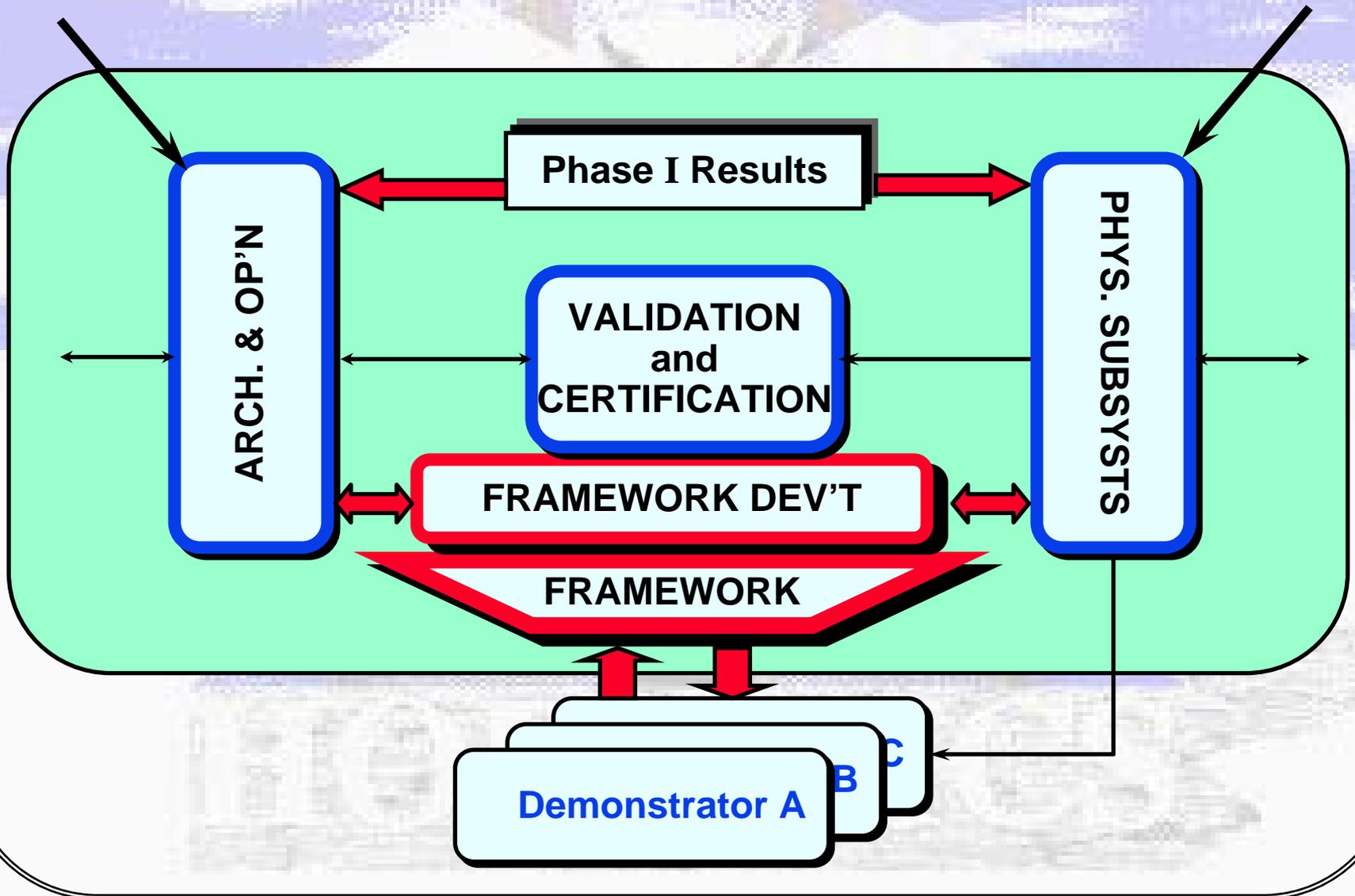


## Phase 1 Industrial Projects

- ◆ Engine Assembly (DaimlerChrysler, IPA - Germany)
- ◆ Robotic Shot Blasting (Blastman Robotics, VTT - Finland)
- ◆ Electric Motor Assembly (Toshiba, Hitachi, Fanuc, Yaskawa - Japan)
- ◆ Electronic Assembly (Alcatel, ATOS - Belgium, Italy)
- ◆ Engine Machining (GM Holden - Australia)



# HMS CONSORTIUM - Phase II





## Phase 2 Work Packages

- ◆ **Holonic Control Devices**
  - technical manufacturing equipment level
- ◆ **Holonic Production Sites and Physical Equipment**
  - manufacturing work cell level with multiple devices
- ◆ **Holonic Production Execution Systems**
  - scheduling and control of Holonic Manufacturing Systems at factory and supply chain levels
- ◆ **Holonic Man-Machine and Emulation Systems**
  - virtual manufacturing and supply chain environment to create test-beds for holonic system implementations



## Conclusions

- ◆ Began with an abstract concept of holons
- ◆ Phase 1 – developed foundation for generic technologies
- ◆ Phase 2 – demonstrating potential for distributed systems
  - Physical equipment
  - Manufacturing work cells
  - Factories
  - Supply chains
- ◆ International acceptance of holonic system architectures
  - Cooperating with FIPA to develop standards
- ◆ HMS provides
  - capability to integrate manufacturing and supply chains
  - offers migration path from legacy systems to fully distributed manufacturing systems.