

HUMAN-CENTERED AUTOMATION: DEVELOPMENT OF A PHILOSOPHY

**Curtis Graeber
and
Charles E. Billings
NASA Ames Research Center**

AVIATION SAFETY/AUTOMATION PROGRAM CONFERENCE
11-12 October 1989
HUMAN-CENTERED AUTOMATION PHILOSOPHY

ATA National Plan, April 1989; pg. 5:

- The **fundamental concern** is the lack of a scientifically based **philosophy of automation** which describes the circumstances under which tasks are appropriately allocated to the machine and/or to the pilot.
 - **Humans** will continue to **manage and direct the NAS** through 2010.
 - Automation should be designed to **assist and augment** the capabilities of the human managers.
 - It is vitally important to develop **human-centered automation** for the piloted cockpit and controller work station.
- NASA's Aviation Safety/Automation Program is founded in large part on these precepts.

IMPLICATIONS OF THE PRECEPTS IN THE NATIONAL PLAN

- An explicit philosophy of automation, and the explicit allocation of functions between humans and machines in the system, are **inextricable**.
 - Both must be approached as **fundamental design issues**.
- By implication, automation can be designed to fulfill any task necessary for effective system functioning.
 - This is not true yet, but we believe it will be within a decade or so, perhaps sooner.
- Despite this automation capability, **humans** are to continue to manage and control the system, for a variety of social and political as well as technical (and probably economic) reasons.
 - Automation should therefore function to **supplement, not to supplant**, the human management and control function in civil air transport.

HUMAN-CENTERED AUTOMATION PHILOSOPHY

- Automation implementation to date has been largely **technology-driven**

highly capable
solid-state
avionics



highly automated flight and
performance management
systems (B747-400)

highly reliable
redundant
distributed
microprocessors



automatic, reconfigurable
aircraft subsystem
management systems (MD-11)

highly sophisticated
fly-by-wire control
and guidance
systems



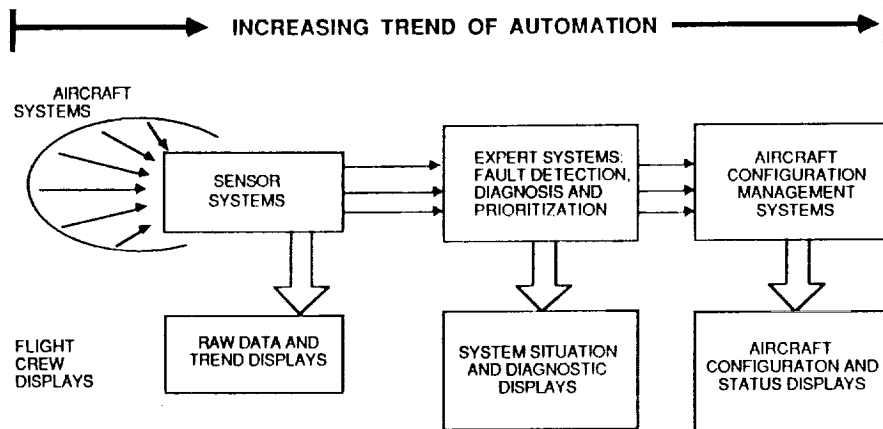
simplified flight control with
comprehensive envelope
protection (A-320)

- *Do these systems, as implemented to date, **supplement**, or tend to **supplant**, the flight crew as manager and controller of its aircraft?*
- *Do they perform the functions that a **human-centered** automation philosophy would allocate to the machine, or to the human?*

- To answer these questions, we must be more explicit. What do we mean by "human-centered automation"? Is it merely a catchy phrase, or a concept that can be defined and evaluated rigorously?

- Because of the central importance of this question, we have given it considerable attention from the genesis of the Aviation Safety/Automation concept and program in 1987, though our work leading up to this program has been in progress for nearly a decade.

HUMAN-CENTERED AUTOMATION PHILOSOPHY



- What does the flight crew need to know?
- The answer depends on the automation philosophy embodied in the aircraft:
 - Why is the flight crew informed?
 - What are they expected to do about the information?
 - Are they informed before, or after, action has been taken?
 - Are they expected to diagnose the problem, choose a course of action, concur with such a choice, carry out the action, or simply to be aware of altered aircraft configuration or status?
- These and other similar questions about increasingly competent and autonomous automated systems have led to a search for a set of irreducible first principles for human-centered aircraft automation.
- Our present construct is shown in the following viewgraph, in the hope that we shall receive constructive criticism from the experts at this workshop.

HUMAN CENTERED AUTOMATION: FIRST PRINCIPLES

- PREMISE: The pilot bears the ultimate responsibility for the safety of any flight operation.
- AXIOM: The human operator must be in command.
- COROLLARIES: The human operator must be involved. To be involved, the human operator must be informed.
-

Because systems are fallible, and in order to remain informed,

The human operator must monitor the system.

Because humans are likewise fallible,

The system should also monitor the human operator.

If monitoring is to be effective,

Each component must have knowledge of the other's intent.

HUMAN-CENTERED AUTOMATION: APPLICATIONS OF CONSTRUCT

We have examined a number of mishaps and proposed systems in terms of this construct:

- China Airlines descent into SFO
 - Needed A/P status information not immediately obvious
 - Flight crew not sufficiently involved
 - Was system effectively in command?
- Air Canada fuel exhaustion
 - FMC system knew flight crew intent
 - But aircraft was unable to inform crew of insufficient fuel
- A proposed system with automatic reconfiguration
 - Should operator be informed of problem, or solution?
 - Should operator be involved in decision to reconfigure?

HUMAN-CENTERED AUTOMATION PHILOSOPHY

We have used this construct to evaluate a limited number of automated systems in current aircraft.

- It points out certain known shortcomings in these systems, especially with respect to information management
- It also suggests ways in which information transfer between humans and systems might be improved

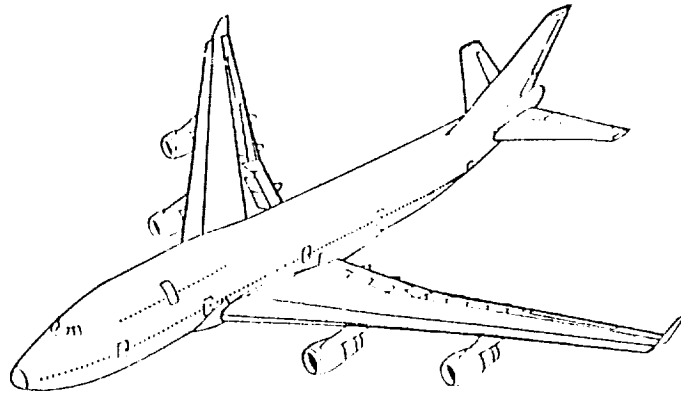
We are using this construct in the design of automated checklists for a series of experiments which will begin this fall

- To determine whether the construct is viable
- To determine how it must be modified or extended to serve as the basis for human-centered automation guidelines in our studies:
 - automated procedures monitoring
 - smart checklists
 - automated diagnostics systems

SUMMARY

- Objectives of this Element of the Program
 - Development of concepts and guidelines
 - Evaluation of competing philosophies
 - Integration of program elements in an intelligent, human-centered automated cockpit
 - Functional validation of these concepts and systems
- Cooperative research with industry in pursuit of these goals
- Hopefully, incorporation of validated concepts into automated interactive cockpit design tools.

**WHY DOES THE 747-400 HAVE NASA-DEVELOPED
WINGLETS BUT NO NASA-DEVELOPED
TAKE-OFF MONITOR?**



**OR, WHY IS TECHNOLOGY TRANSFER HARDER IN FLIGHT DECK
THAN IN AERO, STRUCTURES, AND PROPULSION**

TECHNOLOGY TRANSFER

OUTLINE

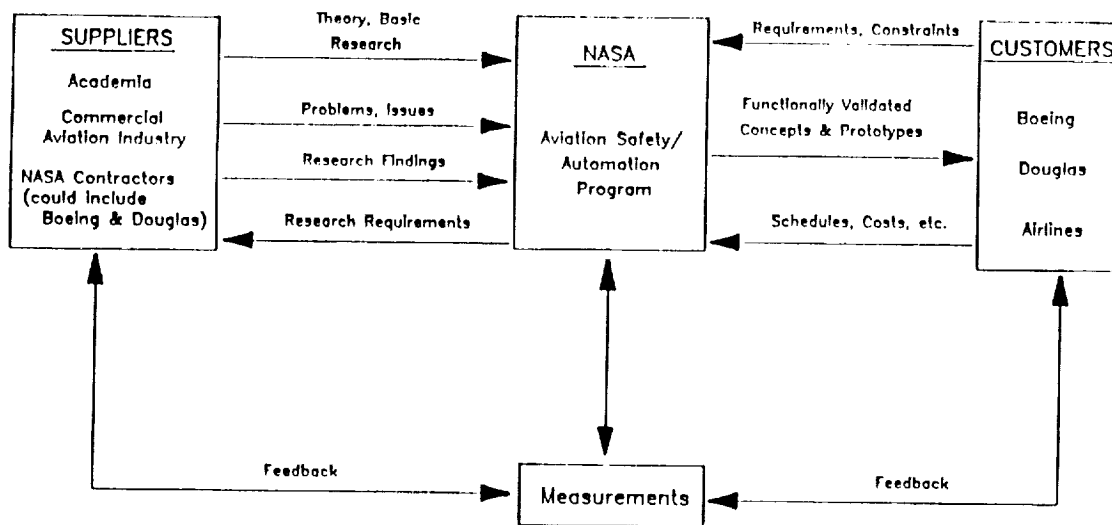
- Goal
- Who
- What
- How
 - Preconditions
 - Impediments
 - Solutions

TECHNOLOGY TRANSFER

GOAL

What is the most effective means for accomplishing the transfer of the program's research products?

ORGANIZATIONAL FRAMEWORK FOR SUCCESSFUL TECHNOLOGY TRANSFER FROM NASA PROGRAMS TO COMMERCIAL TRANSPORT AIRCRAFT



TECHNOLOGY TRANSFER

TO WHOM

- Transport Aircraft Manufacturers
- Business Aircraft Manufacturers
- Avionics Manufacturers
- Airlines
- Pilots
- Controllers
- FAA (Standards, Regulations)
- Research Community (Academic & Industrial Standards)
- Military
- NTSB

AND FROM WHOM

WHAT (OUTPUT)

- Information (Tools, Measures)
- Technology (Systems, Designs, Hardware)
- Methods - Measures
- Guidelines (Training, Operational Design)
- Candidate Designs (Early Prototypes)
- Technical Support

TECHNOLOGY TRANSFER

HOW (APPROACH)

- Preconditions
- Impediments
- Solutions/Suggestions

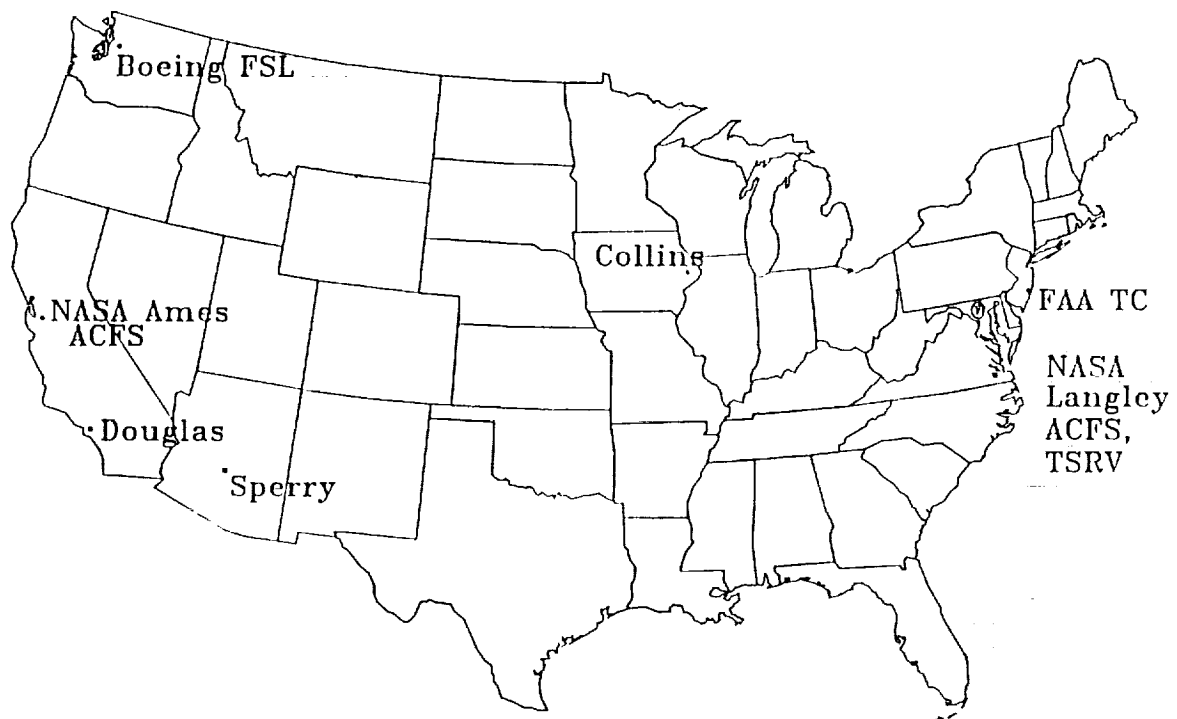
PRECONDITIONS/PROPER ENVIRONMENT

- Clear Goal Statement (Shared Goals)
- Economic Incentives
- Measurement Technology
- Ease of Interaction
- Stable Funding

TECHNOLOGY TRANSFER

IMPEDIMENTS

- Poor Customer Interface
- Geography
- Human Factors Domain (Soft Science)
- NAS Incompatibility
- Type Rating Schemes
- Measurement Techniques
- Lack of Standardization/Cross Feeding Simulation
Scenarios Methodology
- Foreign Competition
- Proprietary Rights
- Allocation of Resources
- Limited Market Place



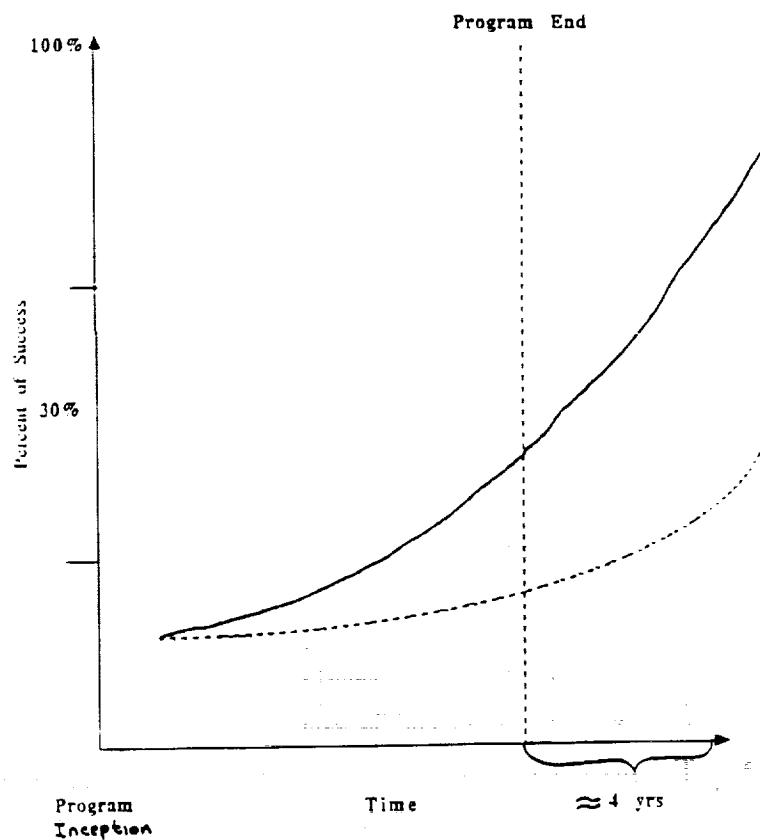
TECHNOLOGY TRANSFER

SOLUTIONS/SUGGESTIONS

- Living Program Plans
- Workshops
- Newsletters (Electronic, Multi-Media, Hyper-Media)
- Networking Technologies - Support Structure
- Temporary Personnel Exchanges
- Cooperative Teams
- Consortium Contracts (Novel Contracting)
- Portability/Compatibility
 - Methods and Scenarios
 - Hardware and Software
- Demonstrations

PROCESS FOR NAS TECHNOLOGY DEVELOPMENT AND TRANSFER

		PARTICIPANTS		
		OPEN TO ALL	INDIVIDUAL CONTRACTORS	INDUSTRY CONSORTIUM (LED BY PROPOSAL) WINNER
PROCESS STEP				
NASA + INDUSTRY	Problem Definition	•		
	Propose Solutions		•	
	Implement Prototype Solutions and Test			•
	Lessons Learned/ Technical Support			•
INDUSTRY	Application of Solution		•	



REALIZATION OF SUCCESS

1. User/Peer Review
 - Demonstrations
 - Simulations
 2. Inclusion in Product Definitions
 3. Citation Frequency
-
4. Implementation
 - FAA Certification
 - Training
 - ATC
 - Aircraft Design
 5. Improved Aviation Safety and Efficiency