Alternative Cognitive Architectures to Support Collaborative Decision Making

Philip Smith, Charles Billings, Roger Chapman,
Jodi Obradovich, Elaine McCoy and Judith Orasanu

Ohio State University, Columbus, Ohio
Ohio University, Athens, Ohio
NASA-Ames Research Center

May 24, 2000

Figure 1

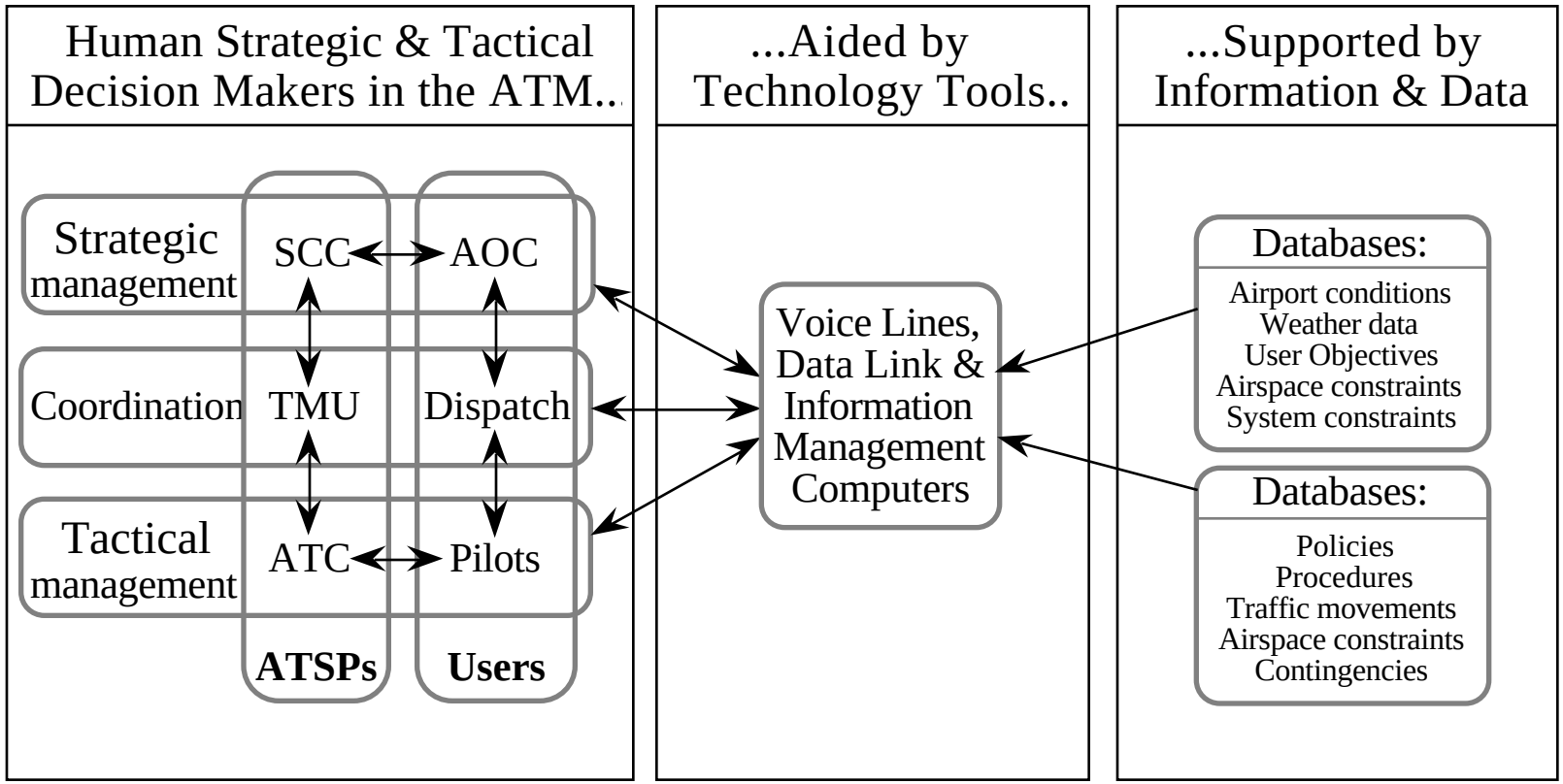

Human Strategic & Tactical Decision Makers in the ATM..
...Aided by Technology Tools..
...Supported by Information & Data
Strategic management
Coordination
Tactical management
SCC
AOC
TMU
Dispatch
ATC
Pilots
ATSPs
Users
Voice Lines, Data Link & Information Management Computers
Databases:
Airport conditions
Weather data
User Objectives
Airspace constraints
System constraints
Databases:
Policies
Procedures
Traffic movements
Airspace constraints
Contingencies

Figure 2

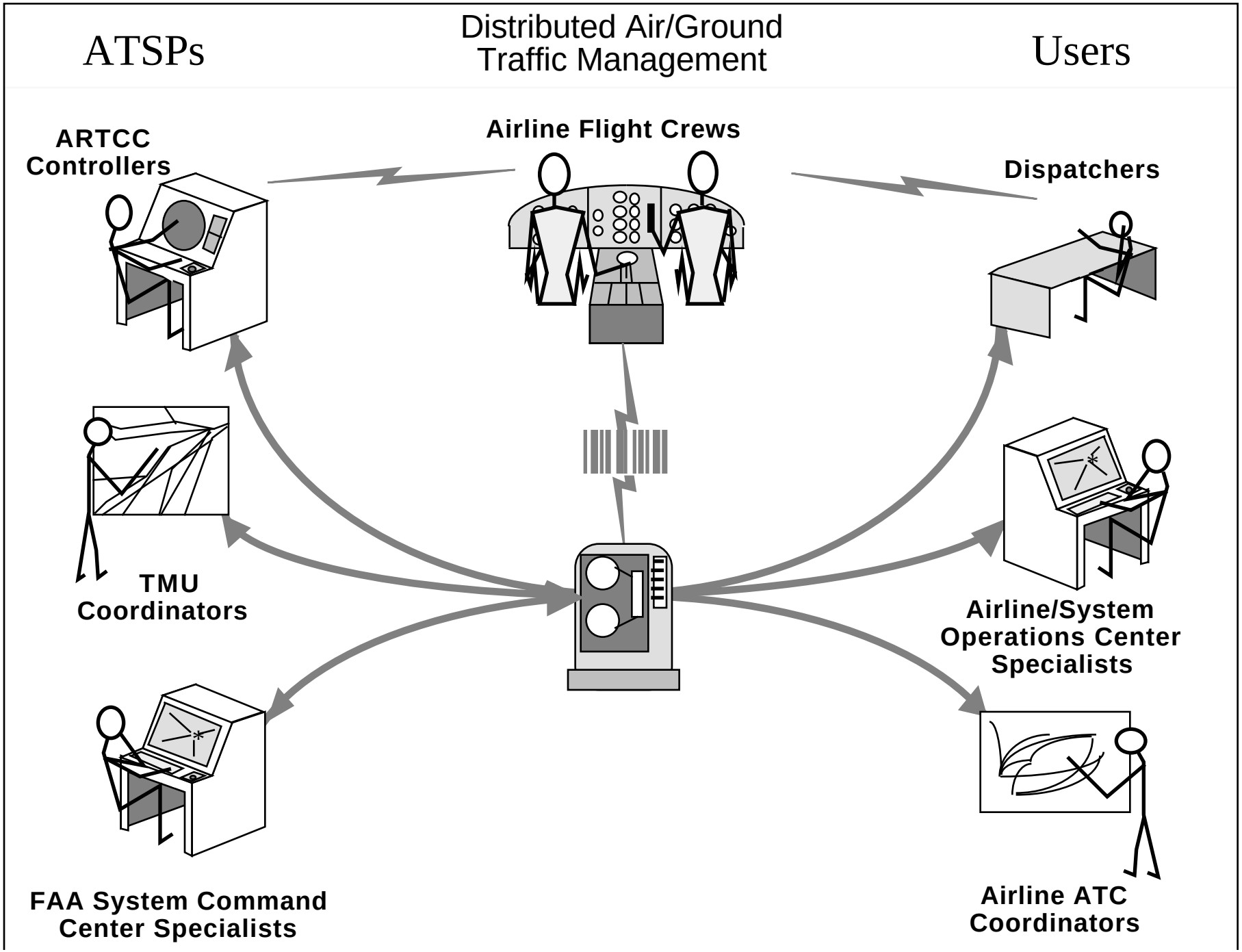

ATSPs
Distributed Air/Ground
Traffic Management
Users
ARTCC
Controllers
Airline Flight Crews
Dispatchers
TMU
Coordinators
Airline/System
Operations Center
Specialists
FAA System Command
Center Specialists
Airline ATC
Coordinators

Figure 3

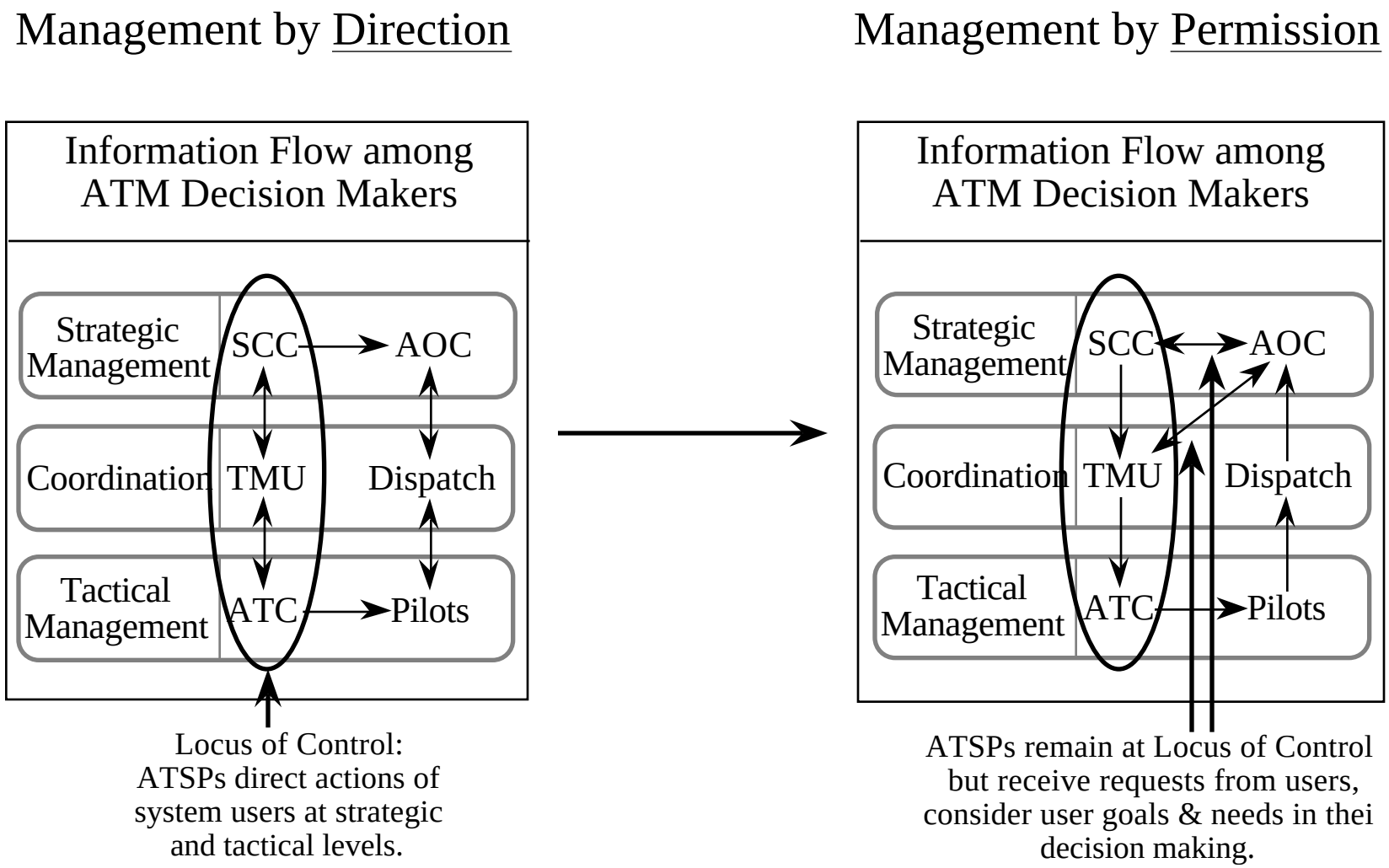

Management by Direction
Management by Permission
Information Flow among ATM Decision Makers
Strategic Management
SCC
AOC
Coordination
TMU
Dispatch
Tactical Management
ATC
Pilots
Locus of Control: ATSPs direct actions of system users at strategic and tactical levels.
Information Flow among ATM Decision Makers
Strategic Management
SCC
AOC
Coordination
TMU
Dispatch
Tactical Management
ATC
Pilots
ATSPs remain at Locus of Control but receive requests from users, consider user goals & needs in thei decision making.

Figure 4

Effects of Original National Route Program

Benefits of new approach:

- Greater information transfer between ATSPs and AOCs, resulting in
  - Increased understanding by users of provider and system constraints
  - increased understanding by providers of user operational & economic needs.
- Substantial fuel and time savings for users.

Weaknesses of new approach:

- Increases in time, therefore personnel, required for one-on-one interactions between TMUs and AOCs concerning requests for exceptions to pref routes
- Increased flexibility for users, though considerable, still felt to be inadequate (because of inherent conservatism on the part of ATSPs?)

Figure 5

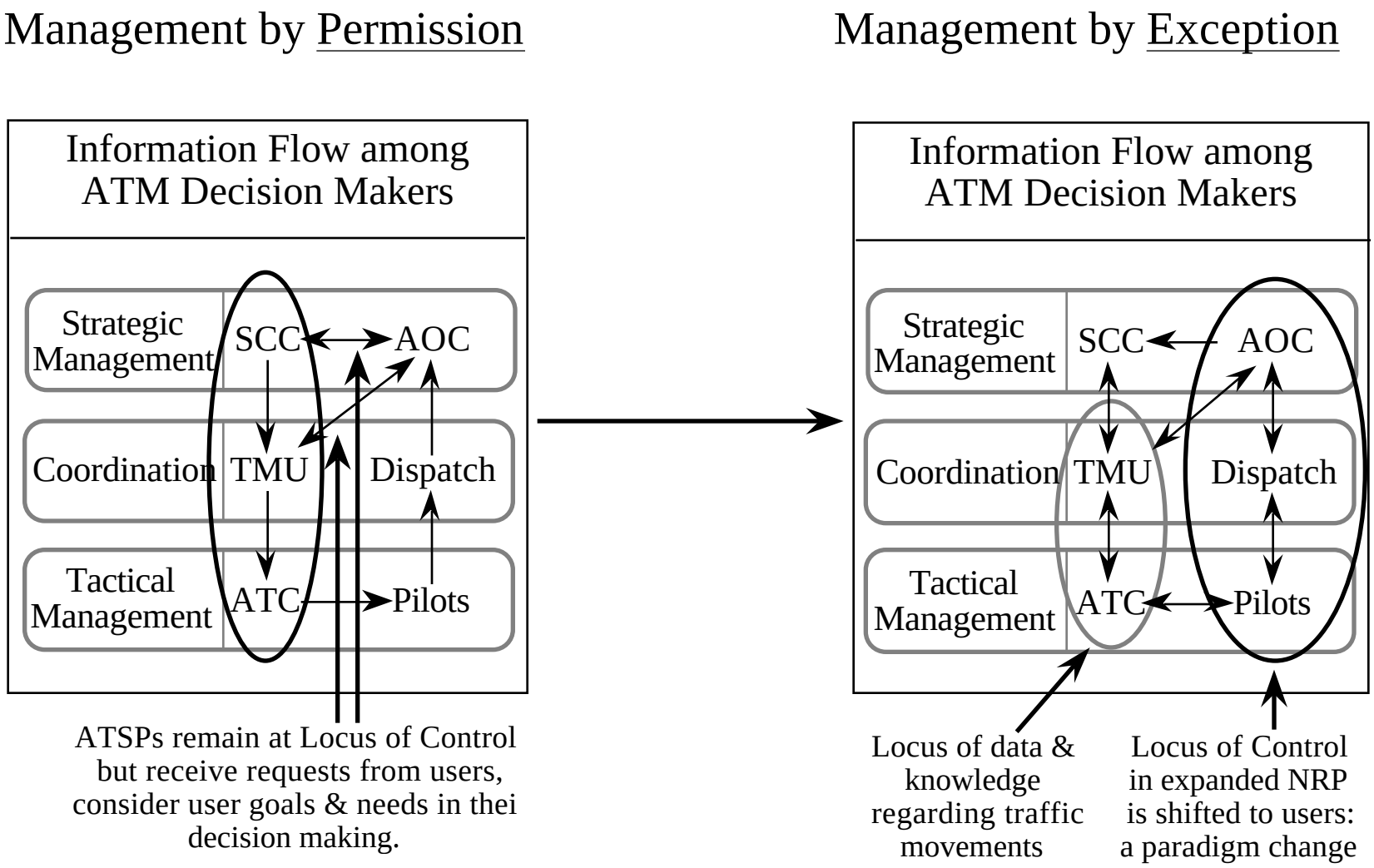

Management by Permission
Management by Exception
Information Flow among ATM Decision Makers
Strategic Management
SCC
AOC
Coordination
TMU
Dispatch
Tactical Management
ATC
Pilots
ATSPs remain at Locus of Control but receive requests from users, consider user goals & needs in thei decision making.
Information Flow among ATM Decision Makers
Strategic Management
SCC
AOC
Coordination
TMU
Dispatch
Tactical Management
ATC
Pilots
Locus of data & knowledge regarding traffic movements
Locus of Control in expanded NRP is shifted to users: a paradigm change

Figure 6

Effects of Expanded National Route Program

Benefits of modified approach:

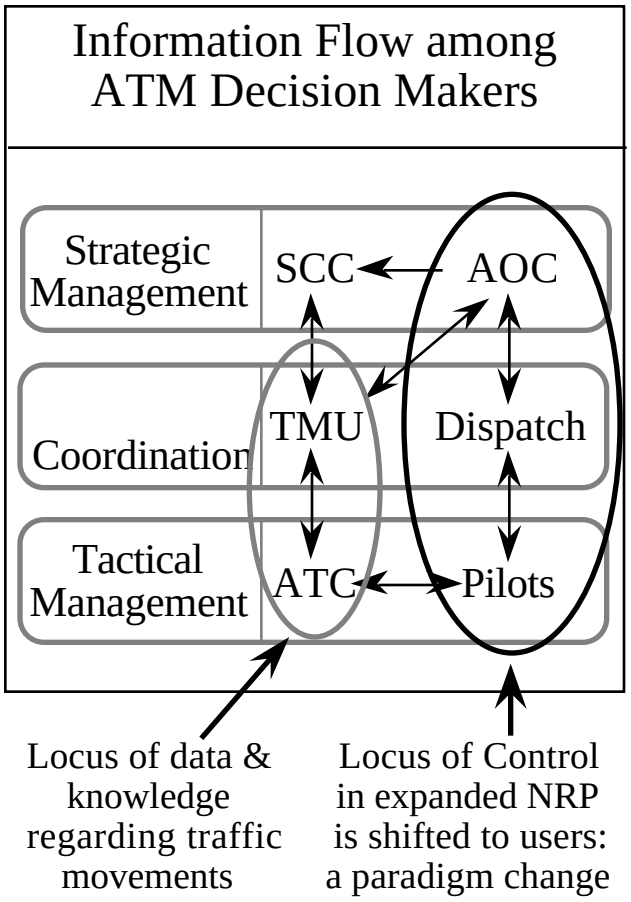
- Greater flexibility for users to accommodate economic & business concerns
- Potentially, an ATM system more directly responsive to user requirements
- Users indicate preferences directly; requested routes are normally approved.

Weaknesses of new approach:

- Significant additional information must be considered by dispatchers if AOCs are to plan effectively around known ATC constraints, but
- Less information & knowledge exchange occurs because interactions are not normally required between users and ATSPs.
- procedure negates to some extent the benefits of original NRP procedures.

Figure 7

General Problem Statement



If system architecture gives one person or group control of the situation, but that person or group

- lacks the data or knowledge to support an effective decision, or
    - does not initiate interaction with persons or groups having this data or knowledge,

Then significant inefficiencies or even safety hazards will result.

Figure 8

Increase Sharing of Knowledge between ATSPs and Users

Detect Recurring Problems

• Post Operations Evaluation Tool *(POET: OSU and Metron, 1999)*

•• Identifies routinely occurring constraints or bottlenecks
•• Displays data and patterns, may permit diagnosis of causes
•• Assists dispatchers to formulate possible solutions

Share Information with Asynchronous Communications Tools

• Collaborative Slide Annotation Tool *(C-SLANT: Smith, 1999)*

•• Permits sharing of problem details between AOCs and TMUs in graphic form, with annotations and associated data
•• Encourages two-way asynchronous discussion of solutions

Contributes to DAG-TM concept elements 0 and 1; potential to improve information management across full spectrum of air transport operations

Figure 9

ATSPs can Increase Flexibility for Users

• ATSPs can offer alternative options to users

•• 20 miles in trail for southbound flights down central Florida peninsula, or
•• Unrestricted operations off Florida east coast

• ATSPs can change parameters of control

•• Instead of holding specific flights at departure points in ground delay program,
•• Allocate arrival slots to air carriers, allow them to fill slots with flights of choice

• ATSPs can make use of new technologies to improve airspace utilization

•• Compression algorithm (Metron) allows slots to be exchanged among airlines when arrival rate restrictions are in effect.
•• Unused slots are reallocated to aircraft with later arrival positions; airline that has vacated earlier position is offered the vacated slot as an incentive to report cancellations and delays.

• Coded Departure Routes

••Another example of soliciting input from carriers regarding their preferences

Figure 10

Shift Locus of Control to Match Locus of Knowledge

- Problem: Increasing demand for high altitude airspace because of use of expanded NRP, and shift from turboprops to jets by regional carriers (eg, 534 vs. 25 in 1999).

- Result: Saturation of high sectors, often at expense of departures and arrivals.

- Possible approach: Provide more detailed information to AOCs and let them sort out the problems cooperatively. If competitive, referee may be necessary.

- Alternative approach: More efficient utilization of lower altitude airspace:

•• The low altitude arrival and departure (LAADR) approach.

- Center TMUs collaborate with airlines to cap some departures at low altitudes in order to unload high altitude sectors. If LAADR may be needed, airlines are notified; they ca indicate flights that should not be capped. Other flights are fueled for lower altitude flight if needed; pilots are notified. Control of departures is shifted back from airlines to TMUs (because ATSPs have the knowledge and data to decide what is needed). Flights are assigned to lower altitudes only if high altitude sectors are heavily loaded. Airlines can constrain the process by indicating their preferences.

Figure 11

Shift Locus of Control to Match Locus of Knowledge

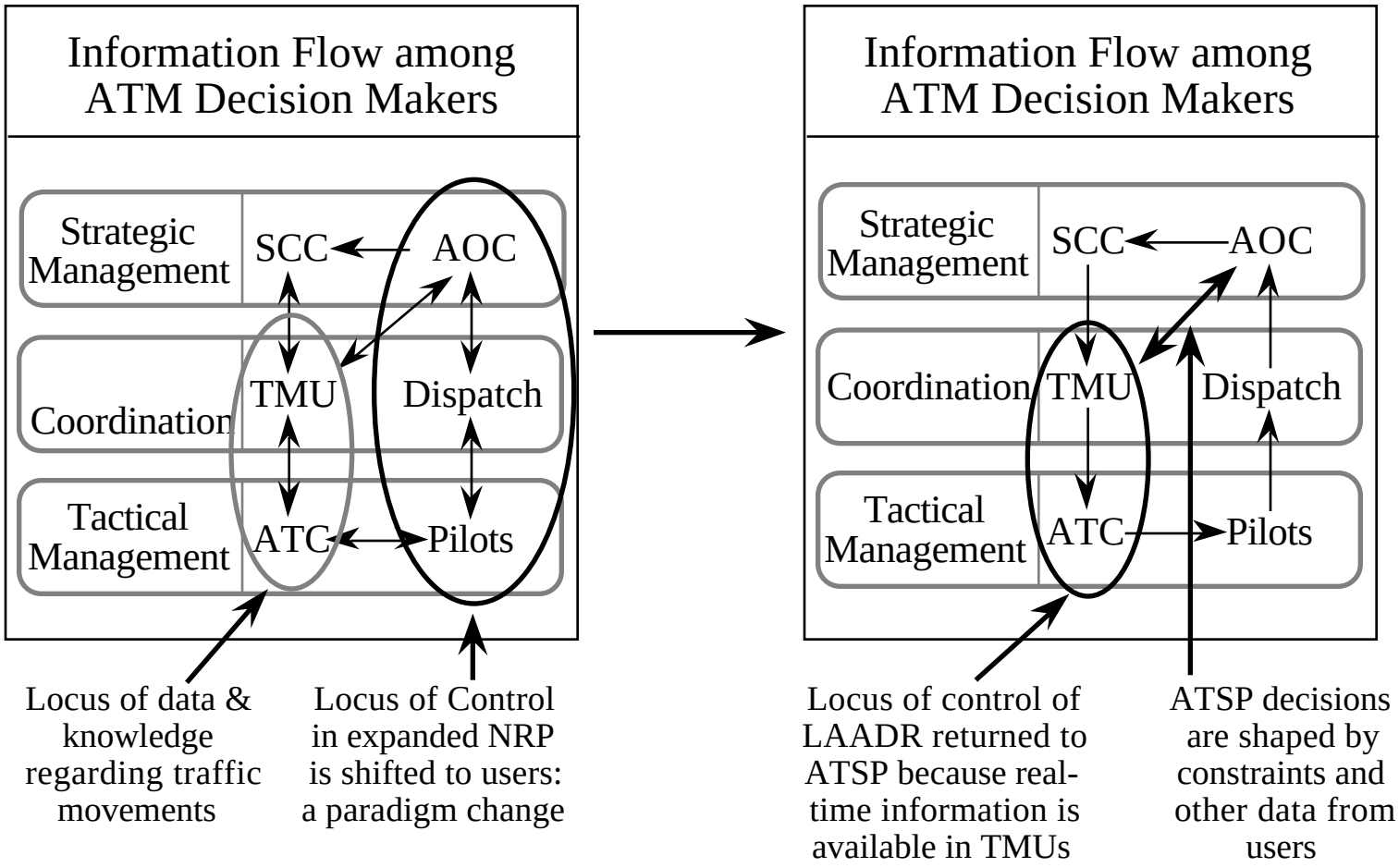


Figure 12

Distributed Decision Making can limit cognitive complexity, balance workload, and permit monitoring to increase redundancy and safety of overall system.

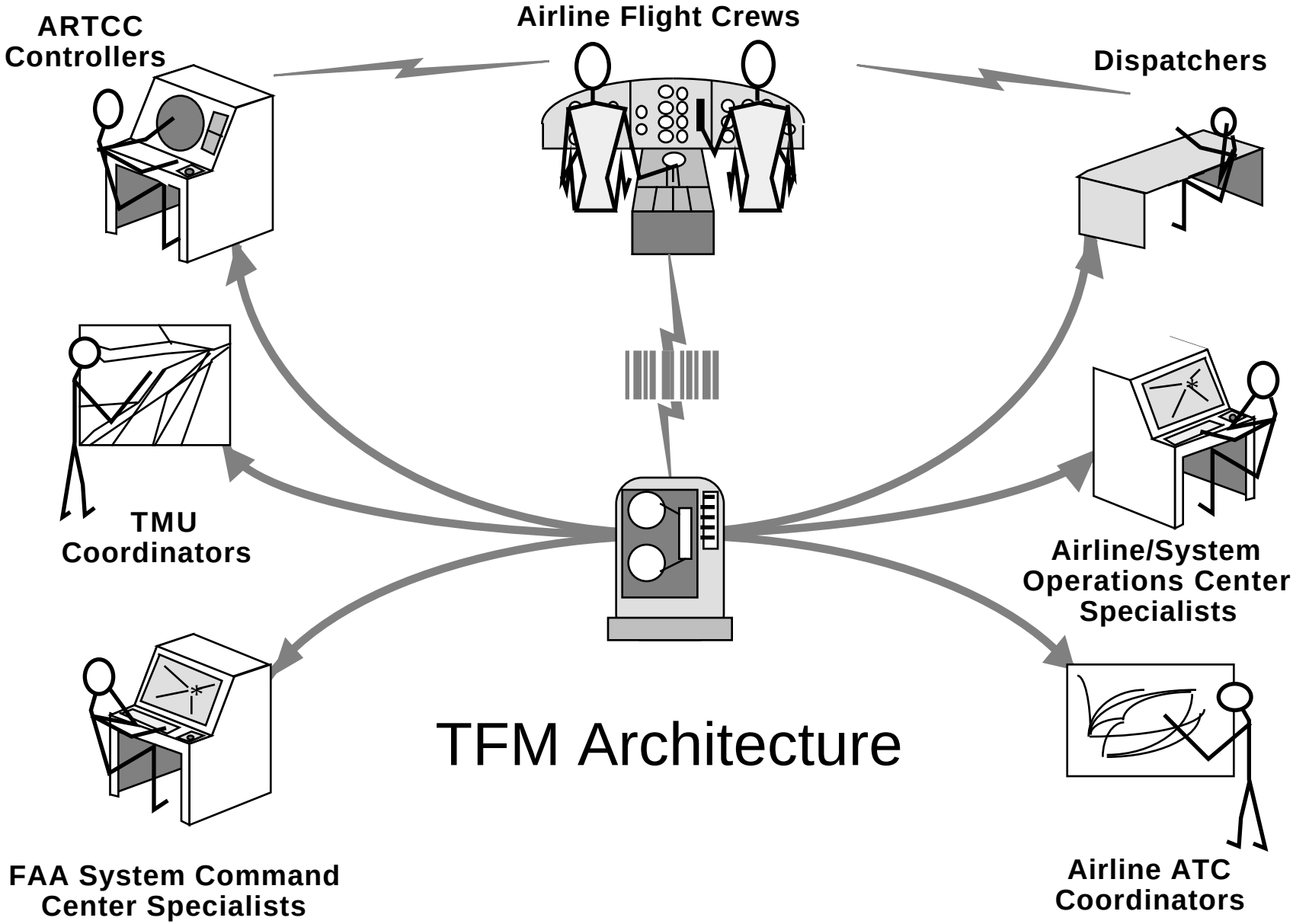


Figure 13

Information Management is at the Heart of the ATM Problem

DAG-TM CE 0: "The efficiency of current NAS operations is limited by the information available for flight planning (by users) and traffic management (by ATSP)."
DAG-TM CE 1: "In the current ATM system, users have limited knowledge of NAS constraints..."

- WHO is best placed to make specific strategic/tactical decisions?
- WHAT does the decision maker need to know?
- WHEN does the decision maker need to know it?
- WHERE is the information most easily available?
- WHO can provide the needed information?
- IN WHAT FORM will it be most easily understood?
- BY WHAT MODALITY is it most effectively delivered?
- HOW can effects of decisions be verified by decision makers? (feedback?)

•• *Answers to these information management questions will enable the development of decision support technology that is optimized for most safe & effective distributed air/ground traffic management.*