Human-Centered Systems Analysis of Oceanic Air Traffic Control: Results from a Reykjavik Center Field Study

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June 19, 2003
Academic:
- University of Iceland and MIT

Government:
- CAA of Iceland and FAA

Research program to evaluate Human Factors in Future Oceanic Air Transportation Systems Architecture
Motivation

- Increased traffic and emphasis on safety in the oceanic environment demand:
  - Reduced separation minima
  - More efficient routing

- Oceanic air traffic control systems and processes are evolving and new technologies (e.g., ADS), integrated information systems, and new procedures (e.g., RVSM) will likely be incorporated.

- This new environment will influence the tasks of the controller and pilot, therefore human factors considerations should be integrated into the design from the beginning
North Atlantic Tracks

courtesy of Tom Reynolds
North Atlantic Traffic
24 – hour period

developed for NICE study
Oceanic Surveillance Limitations

- Delayed surveillance and command path demand large separation requirements
- Missed position reports, which frequently occur become a time sink
- New technologies (e.g., satellite communication and ADS) are slowly being integrated into oceanic operations
Site Visit Methodology

- Reviewed New York & Reykjavik Center Operating Procedures & Job Task Analyses to **formulate preliminary cognitive model**

- Conducted initial site visits to **refine cognitive model**
  - New York Air Traffic Control Center
    - gathered initial understanding of the oceanic environment
    - one 4-hour exploratory observation
  - Reykjavik Air Traffic Control Center
    - four 4-hour focused observations
    - observed:
      - 13 Controllers (5 Oceanic, 8 both Oceanic and radar)
      - 1 Chief Controller
      - 1 Supervisor
      - 1 Training Instructor
Reykjavik Center Observation Results
Overview of Reykjavik Center

- Airspace divided into 4 sectors: North, South, East, West

- 80-90% of South and East sectors are covered by radar (shown in yellow)
Current Reykjavik Workstation

- Workstation in North/West sector
- South/East sectors also have single radar display

Map of Iceland airspace
Notes from Supervisor
Flight Data Processing System

Situation Display
Information Flow – Communication paths

Controller

Voice Communication

FDPS

Electronic Messaging

Workstation

Radar Display

Situation Display

Electronic Flight Strips

Flight Data Server

Communication Relay Service

Other Controllers

Reykjavik ATCC

Other facilities

Controllers

Secondary Radar

Airline

Pilot

Aircraft

Other Aircraft

Flight Data

position & flight data

position & flight data

flight data

position

flight plans

flight plans

flight plan

flight plan

flight plan

flight changes

weather

TCAS

partyline

clearances

pilot requests

other info

Key

- VHF
- HF
- inter-phone

if available
Integrated Cognitive System Model

Controller Cognitive Model

**Situation Awareness**
- **Level 3**: Project
- **Level 2**: Comprehend
- **Level 1**: Perceive

**Monitor** → **Evaluate**
- **Current Plan** → **Re-plan**
- **Knowledge Base**
- **Update information system**
- **Communicate**

**Workstation**
- Radar Display
- Situation Display
- Flight Data Server
- Communication Relay Service
- Voice Communication
- Secondary Radar
- Airline
- Pilot
- Aircraft

**FDPS**
- Electronic Flight Strips
- Electronic Messaging

**Reykjavik ATCC**

**Facility 1**
**Facility 2,...,n**

adapted from Endsley & Pawlak

if available
Integrated Cognitive System Model

Controller Cognitive Model

Level 3: Project
Level 2: Comprehend
Level 1: Perceive

Situation Awareness

Monitor → Evaluate

Mental Model

Current Plan

Update information system

Communicate

Re-plan

Controller

Facility 1
Facility 2,…,n

FDPS

Electronic Flight Strips

Electronic Messaging

Radar Display
Situation Display

Radar

Flight Data Server

Communication Relay Service

Airline

Pilot

Aircraft

Aircraft 2,…,n

Other Controllers

Voice Communication

if available

adapted from Endsley & Pawlak

Reykjavik ATCC
Flight Data Processing System

Limitations cited by controllers:

- **window view**: cannot get a snapshot overview of strips, have to scroll
- **trust**:
  - new system
  - electronic information – have to print out paper strips in case of a breakdown
- **nuisance warnings**: conflict warnings, coordination warnings, etc
Analysis of Conflict Detection Alerts – Ex: Aircraft hand-off

Controller Cognitive Model

Level 3: Project
Level 2: Comprehend
Level 1: Perceive

Situation Awareness

Monitor → Evaluate
Mental Model

Knowledge Base

Current Plan → Re-plan
Update information system
Communicate

Reykjavik ATCC

Workstation

FDPS

Electronic Messaging

Logic

Alert user
Evaluate
FDPS Current Plan
Constraints
Probe new information

Other facility

Controller

adapted from Endsley & Pawlak
Flight strip direction, time, and altitude groupings provide **structure-based abstractions** for controllers:

- Strip arrangement (position matrix) mimics traffic structure
- Color represents direction of flight (westbound are turquoise & eastbound are yellow)
Integrated Cognitive System Model

Controller Cognitive Model

- **Level 3:** Project
- **Level 2:** Comprehend
- **Level 1:** Perceive

**Situation Awareness**

- Monitor
- Evaluate
- Current Plan
- Re-plan
- Communicate

**Workstation**

- Radar Display
- Flight Strips
- Flight Data Server
- Communication Relay Service

**FDPS**

- Electronic Messaging
- Update information system

**Other Controllers**

- Reykjavik ATCC
- Aircraft 2,..,n
- Facility 2,..,n

**Controller Cognitive Model**

- Monitor
- Evaluate
- Current Plan
- Re-plan
- Communicate

- Radar Display
- Flight Strips
- Flight Data Server
- Communication Relay Service

- Situation Display

**Situation Awareness**

- Level 1: Perceive
- Level 2: Comprehend
- Level 3: Project

**Integrated Cognitive System Model**

- Controller
- Aircraft
- Facility

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adapted from Endsley & Pawlak
Situation Display

- Graphically depicts extrapolation of aircraft path based on flight strip assumptions
- Not utilized as much as expected
- **Time constraints** in the procedural sectors encourage a methodical strip comparison, however it is more conducive to use the Situation Display with **spatial constraints**
- Currently, Iceland’s Operating Procedures encourage use of Situation Display to assist in separation, but **require that controllers tactically ensure separation using strips**
- Controllers in mixed environment have to cognitively integrate **nearly continuous information** from radar screen with **discrete information** from Situation Display
Different boundaries negate the advantage of technologies and procedures such as radar, RNP, RVSM, and ADS.

Controllers in mixed equipage environment may not apply reduced separation standards in order to reduce operational complexity, maintain situation awareness and manage workload.

Ex: Non-Radar: 10 minutes
Radar: 3 minutes

Required Navigation Performance (RNP)

- Non-RNP approved
- RNP-10

Ex: Non-RNP approved: 100 nm
RNP-10: 50 nm
Process Analysis

Phase I: Pre-Arrival in Sector

Phase II: Arrival in Sector

Phase III: Traversal through Sector

~30-45 minutes before aircraft reaches airspace boundary

Aircraft enters airspace

Aircraft in sector airspace: arrival – hand-off

based on observations and interviews
Phase I: Pre-Arrival in Sector

- Adjacent facility calls to transfer control
- Flight strip arrives in message center on FDPS

**Procedural Projection to Identify Conflicts**

- Put Flight Strip in flight level grouping
- Compare waypoints for aircraft on same flight level to see if any match
  - If waypoints match along route: compare time to ensure adequate separation

- If there are imminent conflicts: **re-plan** and ask adjacent facility to communicate changes
- If there are conflicts that are not imminent: “tag” strip (under time of potential conflict) with an underlined red flag
Phase II: Arrival in Sector

- CLEARANCE window comes up on FDPS (sent by adjacent facility)
- Check flight strip for underlined “tag”
  - If “tagged”: evaluate situation
  - If there are conflicts: re-plan & modify clearance, by editing NEW PROFILE
- Press PROBE
  - If conflict warning appears: evaluate to determine if it is a false alarm
  - If there is a true conflict: re-plan & modify clearance by editing NEW PROFILE
  - press PROBE again
- Communicate command by either:
  - Pressing CLR
  - Pressing CLRVHF and call pilot
Phase III: *Traversal through Sector*

- **Monitor** for additional information, deviations from “current plan”, and overdue aircraft
- **Re-plan** only when necessary:
  - predicted loss of separation
  - turbulence
  - restrictions from adjacent facilities
  - emergencies
  - special occurrences
  - ...
Structural Abstractions

- Studies show that structure provides the basis for air traffic controller abstractions, which significantly influence cognitive processes and reduce controller workload (Davison, Histon)
- Identified structural abstractions:

**Groupings:**
- Standard Flows: North Atlantic Tracks
- Flight Strip Arrangement

**Critical Points:**
- Position Report Points
Several Reykjavik controllers reported that they are cognitively able to handle more traffic as structure increases.
1. **Delayed surveillance** and **command path**, and **missed position reports** disrupt the controller-centered control loop:
   - The integration of new surveillance (e.g. ADS) and communication (e.g. satellite communication) technologies is necessary to mitigate the problems caused by procedural surveillance.

2. **Nuisance warnings**, **lack of controller trust** in alerts, and the **limited window view** of the electronic flight strips distract the controllers cognitive processes rather than support them:
   - Automation limitations need to be overcome in order to support the controllers cognitive processes.
3. Providing ADS information and fully integrating the Situation Display could innately change the projection task of the controller from a time-based projection to a spatial-based projection, therefore:
   - Consideration should be given to the type (spatial or time) of separation requirements given to the controller in the future

4. The mixed equipage issue of transitioning boundaries of different performance needs to be carefully considered in order to avoid negating the advantage of new technologies and procedures
Future Plans

- Continue to **develop cognitive model**

- Conduct **focused observations at U.S. facilities** for comparative analysis in order to identify similarities and differences between U.S. and Iceland.

- Based on current cognitive model **project the future of oceanic ATC** and the effect of introducing new technologies such as ADS.

- Further **investigation into key issues** identified in conjunction with Tern Systems in Iceland.
Questions

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