HUMAN FACTORS ISSUES IN THE USE OF ARTIFICIAL INTELLIGENCE IN AIR TRAFFIC CONTROL

October 1990 Workshop

Sponsored by NASA and FAA
Hosted by California Polytechnic State University

FINAL REPORT
June 1990 - December 1991
Grant No. NAG 2-669

Stephen Hockaday Principal Investigator
Professor and Chair
Civil/Environmental Engineering Department
and
Director of
Applied Research and Development
Facilities and Activities
California Polytechnic State University
San Luis Obispo, California 93407
(805) 756-5062

Transportation Research Group
Technical Report: TR 91-7
Compiled and Edited by
Sharon Kuhlenschmidt, ARDFA

https://ntrs.nasa.gov/search.jsp?R=19920024959 2018-04-03T18:58:52+00:00Z
ACKNOWLEDGEMENTS

The authors of this report wish to thank George Booth and the Federal Aviation Administration for funding this project. We greatly appreciate the support and participation of Joseph Del Balzo, Executive Director for System Development. We thank Technical Manager Thomas Walsh, for his assistance and continued support throughout this project. We also thank Leonard Tobias, NASA Ames Research Center, for his assistance in printing and distributing the Proceedings.
1. EXECUTIVE SUMMARY OF CONFERENCE PROCEEDINGS

A report by participants in the Human Factors/AI/ATC Workshop at California Polytechnic State University, San Luis Obispo, October 3 through 5, 1990.

Executive Summary
The objective of the workshop was to explore the role of human factors in facilitating the introduction of Artificial Intelligence to advanced ATC automation concepts. The workshop was a follow-up to a previous AI/ATC workshop sponsored by the FAA held at NASA Ames Research Center, February 9 and 10, 1989.

"Artificial Intelligence" is an umbrella term which is continually expanding to cover a variety of techniques where machines are performing actions taken based upon dynamic, external stimuli. AI methods can be implemented using more traditional programming languages such as LISP or PROLOG, or they can be implemented using state-of-the-art techniques such as object-oriented programming, neural nets (hardware or software), and knowledge based expert systems.

As this technology advances and as increasingly powerful computing platforms become available, the use of Artificial Intelligence to enhance Air Traffic Control systems can be realized. Substantial efforts along these lines are already being undertaken at the FAA Technical Center, NASA Ames Research Center, academic institutions, industry and elsewhere.

Although it is clear that the technology is ripe for bringing computer automation to ATC systems, the proper scope and role of automation are not at all apparent. The major concern is how to combine human controllers with computer technology. A wide spectrum of options exists; ranging from using automation only to provide extra tools to augment decision making by human controllers to turning over moment-by-moment control to automated systems and using humans as supervisors and system managers.

Across this spectrum, it is now obvious that the difficulties that occur when tying human and automated systems together must be resolved so that automation can be introduced safely and effectively. The focus of the workshop was to further explore the role of injecting AI into ATC systems; and to identify the human factors that need to be considered for successful application of the technology to present and future ATC systems.

The workshop opened with an address by Joseph Del Balzo, Executive Director for System Development of the FAA. The
workshop participants represented government, academia and industry in Canada, France, the US, and Yugoslavia. After presentations and discussion of several papers on (i) applications of AI to ATC functions and concepts and (ii) identification of air transportation issues with high potential for AI applications, the participants divided into three working sub-groups to consolidate the findings and recommendations of the workshop. The topic areas of the three sub-groups were:

1) Task allocation between humans and computers and the limits of automation;

2) Simulation and testing of AI/ATC systems; and

3) ATC problems to be addresses by AI.

Brief summaries of the groups' conclusions follow.

Task Allocation Between Humans and Computers: The Limits of Automation

The proposed role of the human operator of AI/ATC systems must be evaluated at all stages of ATC system/subsystem design and development. In particular, this evaluation should take place at the beginning of systems development cycles, where systems or operational protocols are being conceived.

The FAA should develop a formal means to insert human factors research and applications early on, and this should continue throughout the design and deployment phases of new or modified ATC systems. The FAA should consider establishing an office with Human Factors specialists who must be in the review cycle of automation design for ATC systems. Projects, whose principal goal is to provide cognitive and perceptual aids for human controllers, should include human factors experts in the design team.

Scientific knowledge about cognitive processes, including their limits and strengths, should be examined to determine which functions should be assigned to humans and those which could be assigned to computers. Reliable information is steadily accumulating identifying the mental operations that people can or can not perform well. Existing tools for modeling human cognition should be employed to characterize the cognitive demands imposed upon human operators by ATC tasks. These tools can be used to guide the collection of objective performance data to ATC tasks.

The FAA should also support research refining and extending cognitive modeling techniques (the mental process by which knowledge is acquired) in ways that tailor them to the ATC domain.
The FAA should support the development of improved methods for analyzing and evaluating new AI applications and techniques in ATC proposals. Specifically, the FAA should support the development of:

1) Guidelines based upon knowledge about human capabilities.

2) Rapid-prototyping tools for developing and testing new Computer-Human Interfaces iteratively.

3) Analysis techniques based on formal cognition models.

**Simulation and Testing of Artificial Intelligence in the Air Traffic Control System**

The role and limitation of AI in the ATC system needs to be evaluated by complementary applications of simulation and testing in an AI/ATC simulation test-bed. An assessment should be made of the various communities involved in human factors research to determine how the technology and results from independent research experiments can be shared and used in concert.

A critical first step in this process is to identify the nature and requirements of experiments that are designed to assess ways in which AI can positively impact the ATC systems. Evaluation criteria must be identified for each experiment to provide a means of assessing the effects of incorporating AI in ATC.

It is recommended that the FAA identify and implement a process for the verification, validation, and accreditation of experimental AI techniques that have high payoff potential for the ATC system. This process should involve a complementary mix of simulation and test activities.

The simulation and test activities should be compared to a common library of FAA accredited scenarios that can serve as a baseline to measure independent experiment results. In this manner a multi-disciplinary ATC community (including human factors experts, system engineers, pilots, controllers, and the entire cross section of ATC professionals), can reach concurrence on the merit of proposed AI techniques. The simulation and test methods should define common interfaces that allow maximum use of available technical and operational resources for experimentation.

Finally, it is recommended that the FAA establish a working group that meets frequently. This working group would serve as a forum to present and review research on AI for ATC, and would develop a common set of standards or guidelines that could be used to
assess the effectiveness of AI techniques as applied within the
ATC system.

ATC Problems To Be Addressed by AI

One of the themes in this group was to break away from the notion
that the FAA needs to begin with grand schemes for using very
sophisticated AI techniques to automate the entire ATC system.
The AI techniques used need not necessarily be "hard" AI as the
term is customarily used. Standard programming languages and
hardware may be appropriate, or it may be desirable to integrate
special AI components into standard computing environments.

In this early stage of development, the FAA should also be
looking for ways to select small and medium-scale problems that
are separable and can be treated reasonably independently from
each other (see list below). The experience gained in creating,
implementing, and--perhaps most importantly--using these systems
will refine the technical approaches and will build confidence in
automated systems in the user community. As controllers
experiment with automated AI components, and as feedback from
their use is assimilated in the laboratory, systems can be
augmented and eventually increase in complexity.

Event histories should be carefully studied to verify the
condition under which system operation is required. Special care
should be given to identifying "rare" events critical to safe
operation.

In an effort to focus energy in the research and application of
AI in ATC, several areas were identified that were considered
ripe for investigation. The list includes both smaller
manageable problems for immediate attack and larger, long term
issues on how future ATC systems could be configured. These
areas are listed here:

Maintenance: Particularly the maintenance of equipment
in remote areas.

Monitoring: Particularly of equipment subject to
maintenance.

Surface Control Management: Taxiing, crossing active
runways, etc.

Scheduling and Planning: Particularly of longer-term
tasks.

Modeling the Controller: With emphasis on implicit
perceptual and cognitive activity, not merely overt
actions.
System Function Allocation: Especially between air and ground systems in the data link environment.

Data Fusion: Integration, interpretation, and use of data presented from various sensors with varying levels of quality.

To summarize results from the three working groups, it is important that the FAA identify areas where AI can positively impact the ATC system starting with small-scale programs and gradually evolving to larger-scale efforts. Definitive methods of verification, validation and accreditation of new AI methods should be developed to provide evidence that will allow the development of confidence in the new AI technologies.

Finally, the research and development of AI for application to the ATC system should include the participation of human factors experts. These experts should focus their expertise on the development of powerful, flexible tools and analytic techniques that can assess the effectiveness of injecting AI into the ATC system.

2. LISTING OF CONFERENCE ATTENDEES

The following list contains the alphabetic listing of persons who attended the October 1990 workshop. Points of contact (addresses, phone, FAX and e-mail information) are included in the listing of those requesting copies of the Proceedings.

John Castonia: Vice President, Technical Programs Illgen Simulation Technologies, Inc.

Dr. Alypios Chatziioanou: ARDFA, California Polytechnic State University (Cal Poly)

Cheryl Crabb: CompEngServ Ltd.

Dr. Geoffrey D. Gosling: Assistant Research Engineer
Institute of Transportation Studies University of California, Berkeley

Dr. Harold Heggestad: MIT Lincoln Laboratory

Dr. Stephen Hockaday: Chair, Dept of Civil/Environmental Engineering, Director of ARDFA, Cal Poly

Dr. James C. Johnston: NASA Ames Research Center
3. POST WORKSHOP ACTIVITIES

Semi-Annual Progress Report:

A Semi-Annual Progress Report covering the period of January 1, 1991 through June 30, 1991, was delivered to Thomas Walsh,
APPENDIX A

LISTING OF ATC HUMAN FACTORS and/or AI PROFESSIONALS

This listing contains the names and addresses of human factors and artificial intelligence professionals who were invited to attend the October 1990 workshop. Each person on this list received a copy of the workshop Proceedings. The addresses listed reflect updates received through 11/30/91.

The names are arranged alphabetically in the format: last name, first name.

<table>
<thead>
<tr>
<th>Name</th>
<th>Address</th>
</tr>
</thead>
</table>
| Allen, Henry    | UFA, Inc.  
335 Boylston Street  
Newton, MA 02159  
(617) 964-5172  
(617) 964-7027 (FAX) |
| Alvania, Dr. Stephen | ARD 100  
Manager, Advanced Traffic Management Systems Program  
Federal Aviation Administration  
800 Independence Ave, S.W.  
Washington, DC 20591 |
| Bergeron, Mr. Hugh | Aerospace Engineer  
M/S 156 A  
NASA Langley Research Center  
20 West Taylor Road  
Hampton, VA 23665 |
| Bird, Dr. Michael** | Smiths Industries  
Aerospace & Defense Systems Inc.  
M/S 128  
4141 Eastern Ave. S.E.  
Grand Rapids, MI 49518-8727  
(616) 241-7000 |
| Bobick, John    | Dir. Aviation Systems Group  
ATAC  
301 Evelyn Ave., Suite B  
Mt. View, CA 94041  
(415) 965-8801  
(415) 964-9036 FAX |
| Booth, George   | Human Factors Program ARD 210  
Federal Aviation Administration  
800 Independence Ave. S. W.  
Washington, DC 20591  
(202) 267-9854 472-4104  
(202) 267-9854 |
Bowen, B. A.  CompEngServ Ltd.  
Suite 300  
19 Fairmont Avenue  
Ottawa, Ontario  
Canada K1Y 1X4  
(613) 722-3008  
(613) 722-5660 (FAX)

Brown, Dr. A.  Carlton University  
Colonelby Drive  
Ottawa, Canada K1S 5B6

Caglayon, Dr. Alper K.  President  
Charles River Analytic Inc.  
55 Wheeler Street  
Cambridge, MA 02138

Castonia, John  Vice President, Technical Programs  
Illgen Simulation Technologies, Inc  
250 Storke Road Suite 10  
Goleta, CA 93117  
(805) 968-8661  
(805) 968-1311 FAX

Chatziioanou, Dr. Alypios  ARDFA  
Cal Poly  
San Luis Obispo, CA 93407  
(805) 756-1119  
(805) 756-1702 FAX

Cottrell, Judy  Director of Corporate Relations  
Division of Engineering  
UCSD R003  
La Jolla, CA 92093-0403  
(619) 534-2776

Crabb, Cheryl  CompEngServ Ltd.  
Suite 300  
19 Fairmont Avenue  
Ottawa, Ontario  
Canada K1Y 1X4  
(613) 722-3008  
(613) 722-5660 FAX

Creedon, Dr. Jergmiah F.  Director Flight Systems  
NASA Langley Research Center  
11 Ames Roar M/S 113  
Hampton, VA 23665-5225
Del Balzo, Joseph
AXD-1
Executive Director for System Development
Federal Aviation Administration
800 Independence Ave. S. W.
Washington, DC 20591
(202) 267-7111
Mike Harrison Special Assistant to Mr. Del Balzo (202) 267-8719.

Dismukes, Dr. R. Key Jr. Chief, Aerospace Human Factor Research Division
M.S. 262-1
NASA Ames Research Center
Moffett Field, CA 94035
(415) 604-5729

Duytschaever, Dirk
Central Flow Management Unit
Brussels

Edwards, Vernon
ARD-100
Manager, Automated En Route ATC Program
Federal Aviation Administration
800 Independence Ave. S. W.
Washington, DC 20591

Ellis, Dr. B.
RAE Farnborough Hants
R177BLD
Great Britain GU14 6TD

Foushay, H. Clayton
AXR-3
Chief Scientific & Tech Advisor Human Factors
Federal Aviation Administration
800 Independence Ave., S. W.
Washington, DC 20591

Garot, Jean-Marc
EXCPTL Center
Orly Sud No. 205
Postal Code 94542
Orly Aerogare CEDEX
France
011-33-69-84-50-00 (?)

Gerstenfeld, Arthur
President UFA Inc.
335 Boylston Street
Newton, MA 02159
(617) 964-5172
(617) 964-7027 FAX
Gosling, Dr. Geoffrey D.  Assistant Research Engineer
Institute of Transportation Studies
109 McLaughlin Hall
University of California
Berkeley, CA 94720
(415) 642-9064
(415) 642-1246 FAX
atclab @ garnet.berkeley.edu EMAIL

Grossberg, Dr. Mitchell  ART-304
Advanced Systems & Facilities Division
Federal Aviation Administration
800 Independence Ave, S. W.
Washington, DC 20591

Hall, Kurt  Intelligent Software Strategies
151 Collingwood
San Francisco, CA 94114

Heggestad, Dr. Harold  Machine Intelligence Group
MIT Lincoln Laboratory
Room M200
244 Wood Street
Lexington, MA 02173
(617) 981-7218
(617)981-4094 FAX
hal @ xne.mit.edu EMAIL

Hockaday, Dr. Stephen  Professor and Chair, Civil/Environmental Engineering Department
Cal Poly State University
ARDFA
San Luis Obispo, CA 93407
(805) 756-5602
(805) 756-1702 FAX

Howell, Goeffry  Chief Scientist Civil Aviation Authority
CAA House
45-59 Kingsway
London WC2 B6TE
England
(01) 832-5833
071-832-5789 Direct line
071 832-6478 FAX

Howell William  Information Systems Division
NASA Langley Research Center
5 Freeman Road, M/S 469
Hampton, VA 23665-5225
(804) 864-7521
Illgen, John D.          President/CEO
Illgen Simulation Tech., Inc.
250 Storke Road
Suite 10
Goleta, CA 93117

Ingleton, Peter         IATA
2000 Peel Street
Montreal, Quebec
Canada H3A 2R4
(514) 844-6311
(514) 844-6727 FAX

Johnston, Dr. James C.  NASA Ames Research Center
MS 262-2
Moffett Field, CA 94035
(415) 604-5686
jcj @eos.arc.nasa.gov EMAIL

Jones, Dr. H. L.        The American Service Corp.
1 Jacob Way
Readly, MA 01867

Jorgensen, Dr. Charles  Chief, Intelligent Systems
Technology Branch
NASA Ames Research Center
MS 244-4
Moffett Field, CA 94035-1000
(415) 604-6025
(415) 467-6997 FAX
jorgensen @ pluto.arc.nasa.gov EMAIL

Karppinen, Noel         Manager Operations Research, C.A.A.
Central Office
G.P.O. Box 367
Canberra, ACT 2601
Australia
011 61 6 268 4058 phone
011 61 6 268 5434 FAX
011 61 6 268 4111 (central switchboard)
011 61 6 257 2489 FAX

Kelly, Raymond          ARD-210
Human Factors Program
Federal Aviation Administration
800 Independence Ave, S.W.
Washington, DC 20591
Krella, Fred
Eurocontrol
B.P. 15
91222 Bretigny-Sur-Orge
CEDEX
France
001-33-1-69-88-75-00
011-33-60-85-15-04 FAX

Kuhlenschmidt, Sharon
ARDFA
Cal Poly
San Luis Obispo, CA 93407
(805) 756-6502
(805) 754-1702 FAX

Lacoss, Dr. Richard
MIT Lincoln Laboratory
244 Wood Street
Lexington, MA 02173
(617) 981-7218

Lee, Dr. Alfred T.
Director, Human Factors Research
Decision Systems
318 State Street
Los Altos, CA 94022
(415) 323-1105
(415) 949-1778 FAX

Levy, Andrew
Intellicorp
2000 Corporate Ridge
Suite 825
McLean, VA 22102
(703) 749-3790
(703) 847-9719 FAX
levy @ intellicorp.com EMAIL

Lucas, Dr. Andrew
Technical Manager
Australian Artificial Intelligence
Institute
1 Grattan St.
Carlton Vic 3053
Australia

Lum, Dr. Henry Jr.
Chief, Information Sciences Division
MS 244-7
NASA Ames Research Center
Moffett Field, CA 94035
(415) 604-6544
Lupinetti, Albert A.  
ACL-1  
Director, Office of Research & Technology Applications  
FAA Technical Center  
ACL-1  
Atlantic City International Airport  
NJ 08405  
(609) 484-6689  

Madni, Azad  
Perceptronics Inc. 115D  
21122 Erwin Street  
Woodland Hills, CA 91367  
(818) 884-3485  

Maignan, Georges  
Director EEC  
Eurocontrol  
B.P. 15  
91220 Bretigny-Sur-Orge  
France  

Mederios, Manuel F.  
DTS-56  
Chief, Automation Applications Division  
Transportation Systems Center  
Kendall Square  
Cambridge, MA 02142  

Myers, Dr. Leonard D.  
Professor, Computer Science  
Cal Poly  
San Luis Obispo, CA 93407  
(805) 756-1252  
(805) 756-6503 FAX  
imyers @ polyslo.calpoly.edu EMAIL  

Olmstead, Jeffrey R.  
ATAC  
301 E. Evelyn Avenue Suite B  
PO Box 370  
Mountain View, CA 93407  
(415) 965-8801  
(415) 964-9036 FAX  

Pararas, Dr. John  
Acting Deputy Director  
MIT Flight Transportation Laboratory  
Room 33-412  
Cambridge, MA 02139  
(617) 253-2424  

Patterson, James  
Federal Aviation Administration  
800 Independence Ave., S. W.  
Washington, DC 20591
Planchon, Pascal  CENA
1 rue de Champagne
91200 Athis - Mons
ORLY SUD 205
94542 ORLY Aerogare Cedex
France
(33-1) 69 84 56 83
(33-1) 69 84 56 97 FAX

Reierson, Dr. James D.  Air Transport Systems Engineering Division
The MITRE Corporation
M/S W336
7525 Colshire Drive
McLean, VA 22102
(703) 883-6543
(703) 883-6478 FAX
m10364 @ mwvm.mitre.org EMAIL

Remington, Dr. Roger  NASA Ames Research Center
M/S 262-2
Moffett Field, CA 94035
(415) 604-6243
roger @ cos.arc.nasa.gov EMAIL

Roske-Hofstrand, Dr. Renate  CTA Incorporated
English Creek Center
The Courtyard, Suite 204
McKee City, NJ 08232
(609) 645-5028
(609) 645-5054 FAX

Schlossberg, Jon L.  Senior Scientist
Lockheed AI Center
96-20 B/254 F
3251 Hanover Street
Palo Alto, CA 94304

Scott, Barry  Mgr. FAA/NASA R&D Field Office
MS 210-2
NASA Ames Research Center
Moffett Field, CA 94035

Smith, Ian  Software Kinetics Ltd.
65 Iber Road
Stittsville, Ontario
Canada K2S 1E7
(613) 831-0888
(613) 721-6217 (home)
(613) 831-1836 FAX
Smith, Rick
Southwestern Area Sales
Gensym Corporation
5150 East Pacific Coast Highway
Suite 233
Long Beach, CA 90804

Spencer, David
Senior Staff
MIT Lincoln Laboratory
244 Wood Street
Lexington, MA 02173-0073
(617) 981-3389

Steinmetz, George
Head, Advanced Transport Operating
Systems Program Office
NASA Langley Research Center
6 East Taylor Road, M/S 265
Hampton, VA 23665-5225

Sullivan, Dr. Edward
ARDFA
Cal Poly
San Luis Obispo, CA 93407
(805) 756-1166
(805) 756-1702

Sullivan, Dr. Joseph W.
Technology Development Manager
Lockheed Artificial Intelligence Center
Orgn 96-20, Bldg 259
3251 Hanover Street
Palo Alto, CA 94304-1191
(415) 354-5213

Thompson, Dr. David
Applications Program Manager,
Artificial Intelligence Research Branch
NASA Ames Research Center
MS 244-14
Moffett Field, CA 94035

Tobias, Dr. Leonard
Senior Research Scientist
MS 210-9
NASA Ames Research Center
Moffett Field, CA 94035
(415) 604-5430
(415) 604-3950 FAX

Tosic, Dr. Vojin
Air Transportation Department
Transportation and Traffic Engineering
University of Belgrade
Belgrade Yugoslavia
Vojvode Stepe 305
011 38 11 493-211
011 38 11 466-294 FAX
Tumelin, Jean-Claude
AI Project Leader
Eurocontrol
B.P. 15
91222 Bretigny-Sur-Orge
CEDEX
France
001-33-1-69-88-75-00
011-33-60-85-15-04 FAX

Tuttle, David
ARD-200
Manager, System Technology Division
Federal Aviation Administration
800 Independence Ave., S.W.
Washington, DC 20591
(202) 267-3337

Van Woortmann, Berghuis
NLR
P.O. Box 90502
Anthony Fokkerweg # 2
1006 B M Amsterdam
31-20-511-3113 FAX

Walsh, Dr. Thomas M.
Mgr. Federal Aviation Administration
Engineering Field Office
6 East Taylor Road, M/S 250
NASA Langley Research Center
Hampton, VA 22102-3481

Wetherby, Dr. Bruce C.
The MITRE Corporation
MS W175
7525 Colshire Drive
McLean, VA 22102-3481
(703) 883-6543
(703) 883-6478 FAX

Wein, Robert S.
AFW-1
Director, Facility System Engineering Service
Federal Aviation Administration
800 Independence Ave, S.W.
Washington, DC 20591

Wesson, Dr. Robert
Wesson International
500 So. Capital of Texas Highway
Building 5, Suite 200
Austin, TX 78746
(512) 328-0100
White, William
ARD-210
Manager, Human Factors Program
Federal Aviation Administration
800 Independence Ave. S. W.
Washington, DC 20091
(202) 267-8523

Wiley, John
ACD-350
Manager, Advanced Systems Technology
FAA Technical Center
Atlantic City International Airport,
NJ 08405

Winter, Heinz
Director Institute of Flight Guidance
DLR
P. O. Box 3267
3300 Braunschweig
Germany

Zacharias, Dr. Greg L.
Principle Scientist
Charles River Analytic Inc.
55 Wheeler Street
Cambridge, MA 02138
(617) 491-3474

Zaidman, Steve
ARD-1
Acting Director R & D Service
Federal Aviation Administration
800 Independence Ave. S. W.
Washington, DC 20591

Zellweger, Dr. Andres
AOR-1
Director Operations Research Service
Federal Aviation Administration
800 Independence Ave. S.W.
Washington, DC 20591

** Dr. Bird wrote that he was no longer in this field.
APPENDIX B

THE PROCEEDINGS
(under separate cover)

Advanced Computer Technology
for
National Airspace System

Human Factors Issues
in the Use of
Artificial Intelligence
in
Air Traffic Control