U.S. Department
of Transportation

Federal Aviation Administration

DOT/FAA/AR-99/39
DOT/VNTSC-FAA-99-6

Human Factors for Air Traffic Control Specialists:

A User's Manual for Your Brain

Sponsored, in part, by The Air Traffic Control Association

This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161

Final Report
November 1999

Human Factors for Air Traffic Control Specialists: A User's Manual for Your Brain

Kim M. Cardosi, Ph.D.
U. S. Department of Transportation
Research and Special Programs Administration
Volpe National Transportation Systems Center

With Contributions From:

Earl S. Stein, Ph.D.
Federal Aviation Administration
William J. Hughes Technical Center

Carol A. Manning, Ph.D.
Federal Aviation Administration
Civil Aeromedical Institute

Daniel J. Hannon, Ph.D.
Hannon Consulting

Illustrations by:

Brian J. Fallon
Federal Aviation Administration
New York TRACON

Daniel J. Hannon, Ph.D.
Hannon Consulting

REPORT DOCUMENTATION PAGE			**Form Approved OMB No. 0704-0188**

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE November 1999	3. REPORT TYPE AND DATES COVERED Final Report February - May 1999

4. TITLE AND SUBTITLE Human Factors for Air Traffic Control Specialists: A User's Manual for Your Brain	5. FUNDING NUMBERS FA9L1/A9112
6. AUTHOR(S) Kim M. Cardosi, Ph.D.	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Department of Transportation John A. Volpe National Transportation Systems Center Research and Development Administration Transportation Systems Center Cambridge, MA 02142-1093	8. PERFORMING ORGANIZATION REPORT NUMBER DOT/VNTSC-FAA-99-6
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Department of Transportation Federal Aviation Administration Research and Development Service 800 Independence Avenue, SW Washington, DC 20591	10.SPONSORING/ MONITORING AGENCY REPORT NUMBER DOT/FAA/AR-99/39
11. SUPPLEMENTARY NOTES	
12a. DISTRIBUTION/AVAILABILITY STATEMENT This document is available to the public through the National Technical Information Service, Springfield, VA 22161	12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

This document presents the findings of human factors research and other information useful to air traffic control specialists in a succinct and easy-to-read format. Topics include: controller-pilot voice communications, memory, fatigue, and the effects of stress on information processing. Techniques are presented for: helping to reduce the probability of errors in voice communications, remembering specific information, identifying signs of stress that could affect performance, and reducing fatigue.

14. SUBJECT TERMS Air traffic control, human factors, fatigue, controller-pilot voice communications	15. NUMBER OF PAGES 56
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	

Preface

This work was sponsored by the Federal Aviation Administration's Office of the Chief Scientific and Technical Advisor for Human Factors (AAR-100). We are very grateful to Lawrence Cole (AAR-100) for his technical guidance, administrative support, brilliant suggestions, and good cheer.

METRIC/ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in) = 2.5 centimeters (cm)
1 foot (ft) = 30 centimeters (cm)
1 yard (yd) = 0.9 meter (m)
1 mile (mi) = 1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2) = 6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2) = 0.09 square meter (m^2)
1 square yard (sq yd, yd^2) = 0.8 square meter (m^2)
1 square mile (sq mi, mi^2) = 2.6 square kilometers (km^2)
1 acre = 0.4 hectare (he) = 4,000 square meters (m^2)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz) = 28 grams (gm)
1 pound (lb) = 0.45 kilogram (kg)
1 short ton = 2,000 pounds (lb) = 0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp) = 5 milliliters (ml)
1 tablespoon (tbsp) = 15 milliliters (ml)
1 fluid ounce (fl oz) = 30 milliliters (ml)
1 cup (c) = 0.24 liter (l)
1 pint (pt) = 0.47 liter (l)
1 quart (qt) = 0.96 liter (l)
1 gallon (gal) = 3.8 liters (l)
1 cubic foot (cu ft, ft^3) = 0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3) = 0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

[(x-32)(5/9)] °F = y °C

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm) = 0.04 inch (in)
1 centimeter (cm) = 0.4 inch (in)
1 meter (m) = 3.3 feet (ft)
1 meter (m) = 1.1 yards (yd)
1 kilometer (km) = 0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm^2) = 0.16 square inch (sq in, in^2)
1 square meter (m^2) = 1.2 square yards (sq yd, yd^2)
1 square kilometer (km^2) = 0.4 square mile (sq mi, mi^2)
10,000 square meters (m^2) = 1 hectare (ha) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gm) = 0.036 ounce (oz)
1 kilogram (kg) = 2.2 pounds (lb)
1 tonne (t) = 1,000 kilograms (kg)
= 1.1 short tons

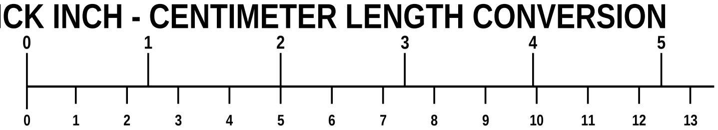
VOLUME (APPROXIMATE)

1 milliliter (ml) = 0.03 fluid ounce (fl oz)
1 liter (l) = 2.1 pints (pt)
1 liter (l) = 1.06 quarts (qt)
1 liter (l) = 0.26 gallon (gal)
1 cubic meter (m^3) = 36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3) = 1.3 cubic yards (cu yd, yd^3)

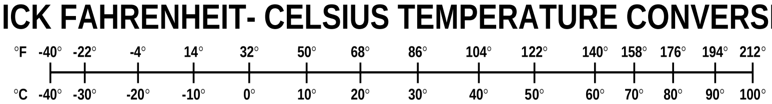
TEMPERATURE (EXACT)

[(9/5) y + 32] °C = x °F

QUICK INCH - CENTIMETER LENGTH CONVERSION



QUICK FAHRENHEIT- CELSIUS TEMPERATURE CONVERSION



For more exact and or other conversion factors, see NIST Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50 SD Catalog No. C13 10286

Updated 6/17/98

About the Authors

Kim Cardosi has a Ph.D. in experimental psychology with an emphasis in visual perception, and a private pilot's certificate. She has been conducting studies at the Volpe Center in ATC human factors and working with controllers for over 10 years. In addition to many government reports and articles in scientific journals, Kim has written for *The NATCA Voice* and *Air Line Pilot* and was co-editor of *Human Factors in the Design and Evaluation of Air Traffic Control Systems.* She currently conducts studies on the effects of color coding on ATC displays and is working with NASA-Ames Research Center and the William J. Hughes Technical Center on a study of "free flight".

Brian J. Fallon is an FAA controller at the New York TRACON and a private pilot. He is also the NATCA Safety Representative for the NY TRACON and an associate editor for the NATCA Voice, "a national grassroots newsletter written by controllers, for controllers". As a hobby, Brian likes to draw aviation-oriented cartoons, some of which are seen in *The NATCA Voice*. Having a keen interest in human factors, Brian enthusiastically volunteered to collaborate on this effort to help ensure that this government report was like no other.

Daniel J. Hannon has a Ph.D. in experimental psychology with an emphasis in color perception and a natural talent for drawing. In previous lives he has been a university professor, flight deck and ATC human factors research psychologist, the Educational Technology Director for the Woburn public school system in Massachusetts, and has consulted for the New York Stock Exchange on the design of their displays. He is currently at the Volpe Center and continues to consult on issues involving color perception and the use of color on displays.

Carol Manning is an engineering research psychologist in the Human Factors Research Laboratory at the FAA's Civil Aeromedical Institute (CAMI), located in Oklahoma City, OK. Carol has a Ph.D. in experimental psychology with an emphasis in decision theory and has been with CAMI since 1983. Carol has conducted research on validation of Air Traffic Control Specialist (ATCS) selection procedures, evaluation of ATCS field training programs, and identification of aptitude requirements for ATCSs who will operate future automated systems. She has participated in a number of studies that investigated the use of flight progress strips in en route air traffic control. She is currently involved in a project to develop objective measures of ATCS taskload and performance using available System Analysis Report (SAR) data. These measures will be used to evaluate the effectiveness of new ATC system concepts.

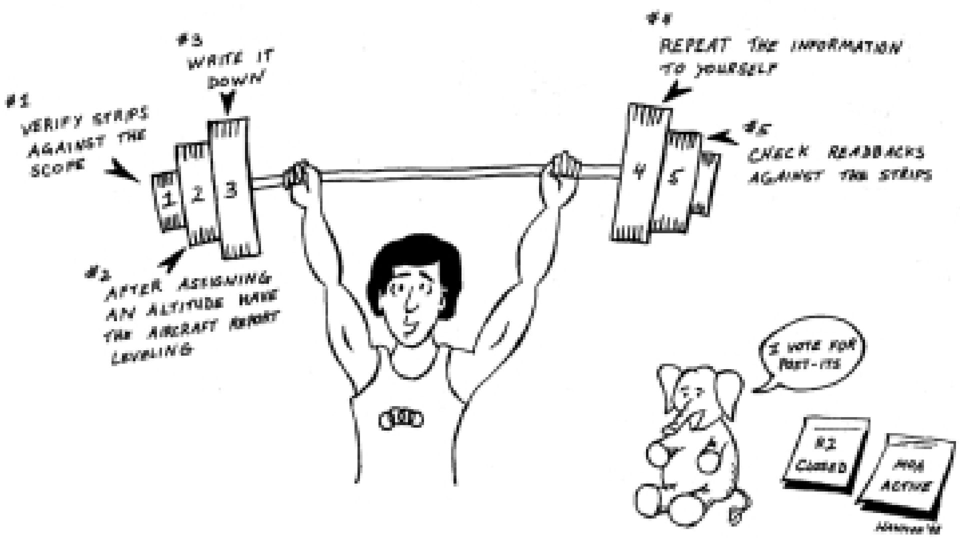
Earl Stein is an engineering research psychologist and the manager of the NAS Human Factors Branch at the FAA's William J. Hughes Technical Center. After receiving his Ph.D., he spent six years in the US Army as a Health Services Research Psychologist. After active duty, and prior to coming to the FAA in 1981, he worked for the Army Research Institute for the Behavioral and Social Sciences developing and testing training concepts. Dr. Stein has conducted extensive research in the areas of eye movements and memory in ATC and is the author of *The Controller Memory Guide: Concepts From the Field*. Dr. Stein is currently the technical lead for ATC human factors specializing in longer-term research, such as evaluation of new concepts and procedures. Dr. Stein is the coeditor of a new book: *Human Factors in Air Traffic Control*.

Table of Contents

Chapter 1

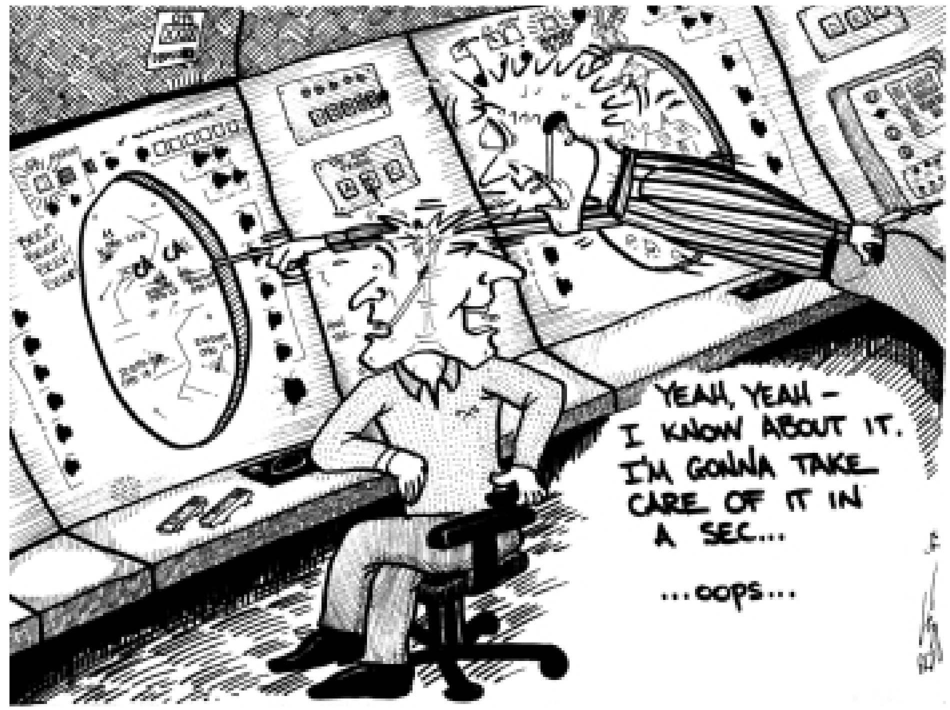
An Elephant Might Never Forget, but We're not that Lucky: How to Make the Most of the Memory you Have.

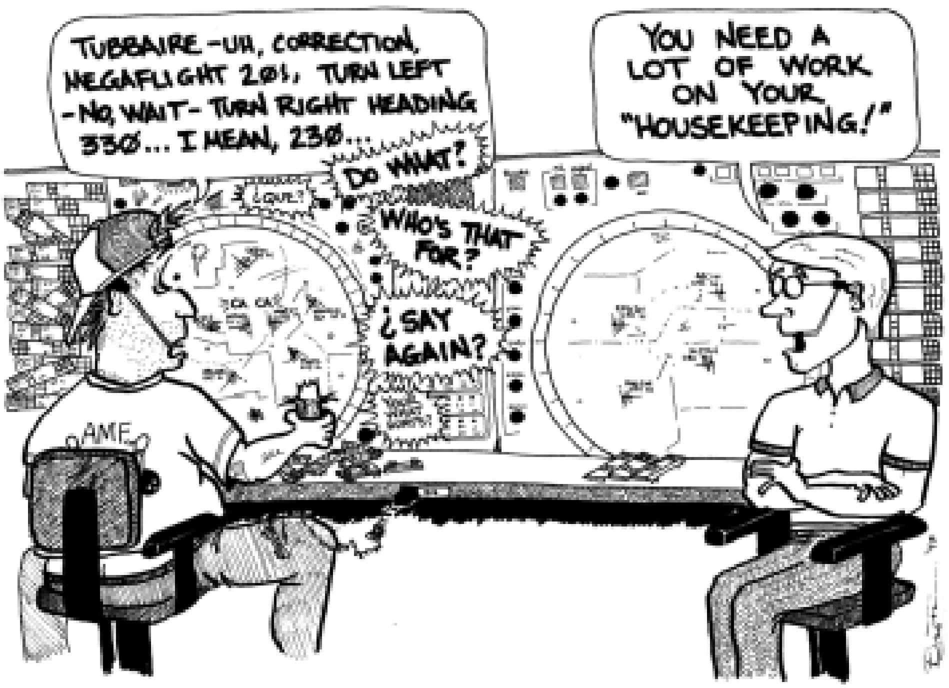
Human Memory is unreliable and needs all the help it can get. Observe the memory-joggers used by other controllers and use whatever cues work for you.



"Working" with specific information helps to strengthen your memory for that information. Even the simple act of writing something down can help you to remember it.

Some things, such as unusual circumstances that pose no danger or require no immediate action, are easier to forget than others. Even in low workload conditions, distractions can clobber short-term or "working" memory. Get a situation back to normal, while you're still thinking about it- otherwise you might forget about it or think you already did something you only planned on doing.

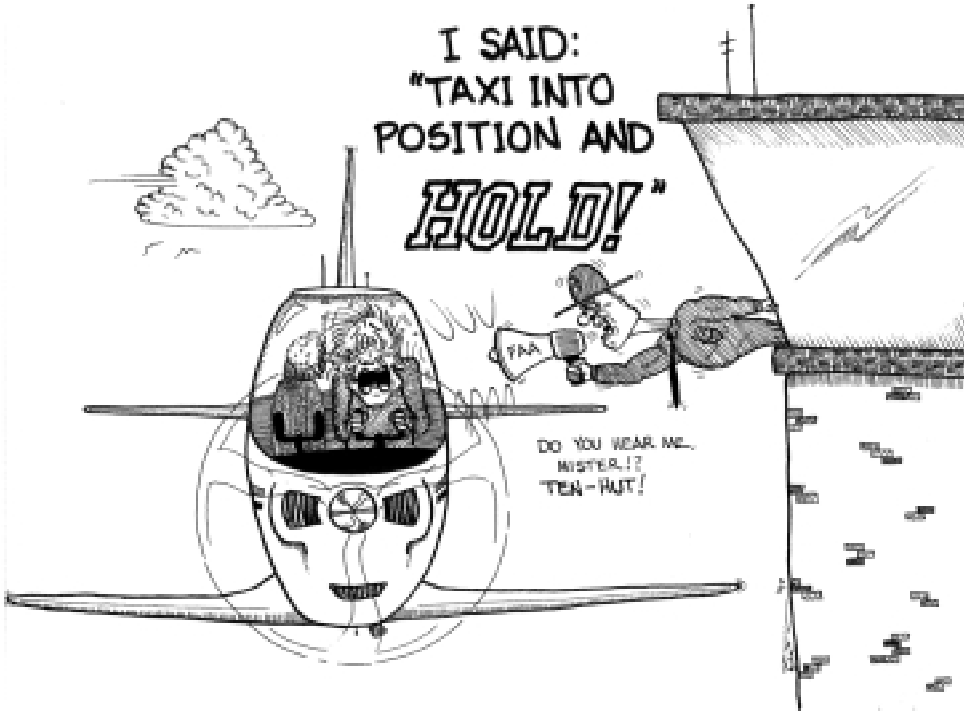




Do whatever you can to unclutter your screen and categorize information.

For example, some facilities use different color strip holders for departures and arrivals. Another example of useful categorization is shortening the data blocks (or the leader line to zero) after switching an aircraft to another frequency.[1]


I STILL FEEL LIKE I'M FORGETTING SOMETHING

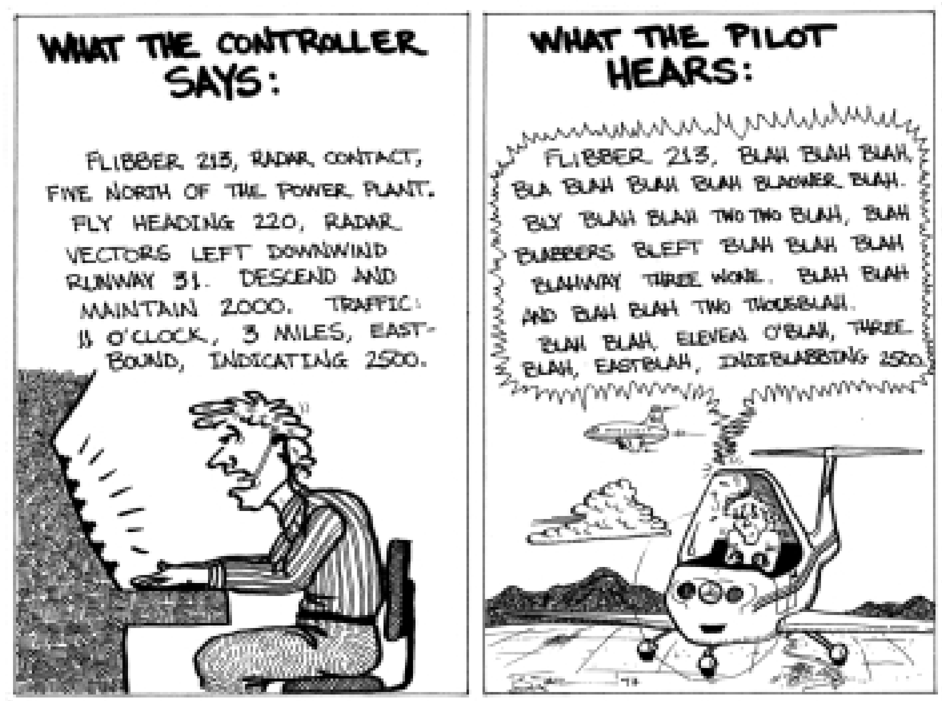


Chapter 2

Controller-Pilot Communications: How to talk to Pilots so They'll Hear What You Want Them to Hear

Give pilots no more than three pieces of information in a single transmission.

The complexity of the controller's transmission has a direct effect on the pilot's ability to remember it - there are fewer readback errors and requests for repeats with short and simple transmissions.[2,3]

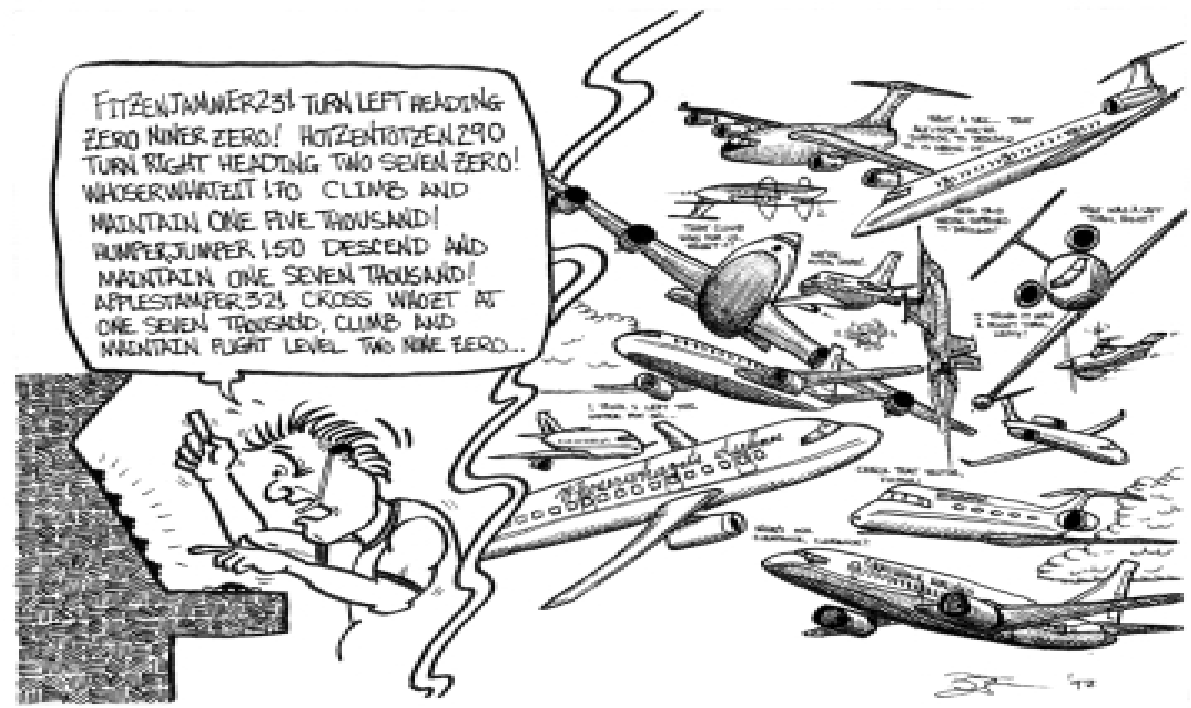


Many different studies show that, on the ground and in the air, cramming too much information in a single transmission can cause problems.

In a study of incident reports submitted by pilots and controllers, “multiple instructions given in the same ATC transmission” were associated with 49% of altitude deviations and 48% of the potential altitude deviations.[4]

A study of en route (ARTCC) voice tapes showed a 1-3% miscommunication rate (i.e., readback errors and requests for repeats) for clearances containing one to four pieces of information and an 8% rate for transmissions containing five or more elements. Clearances containing five or more pieces of information made up only 4% of the messages examined, but accounted for 26% of the readback errors found in the study.[3]

Almost two-thirds of the pilots who said they had difficulties in remembering ATC ground instructions said that ATC issues too much information too rapidly.[5]

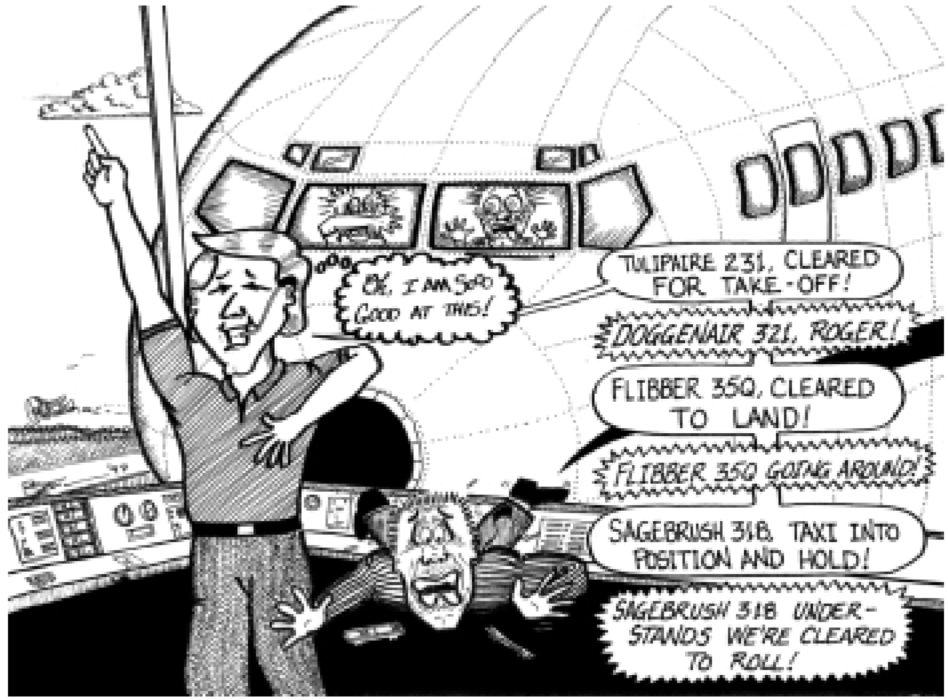


Avoid issuing strings of instructions to different aircraft.
A pilot's memory for an instruction is hindered by extraneous information presented before and after it.

When issuing a clearance that is different from what the pilot was told to expect, EMPHASIZE the difference.

A study of Aviation Safety Reporting System (ASRS) reports found that 33% of the communication errors between the cockpit and ATC that resulted in runway transgressions identified pilot expectations as contributing to the error.[6]

We are all set up to hear what we expect to hear. This is one reason why catching readback errors is such a difficult task. Use the pilots' readbacks like you do any other piece of information. Actively listen to the readbacks and check them against any other information (such as strip notations). This will help to guard against hearback errors and serve as a check that you issued the clearance that you intended to issue.



Studies of voice tapes from actual operations reveal that readback errors occur in less than one percent of all controller transmissions.[3,7,8,9,10] On average, 66% of these readback errors are corrected by the controller, but the proportion of readback errors corrected by the controller varies widely with the ATC environment. While en route controllers corrected 89% of the readback errors,[3] only 50% of the readback errors on the ground frequency were corrected.[7] On the TRACON and local control frequencies, controllers corrected 60% and 63%, respectively.[8,9]

To err is Human. Unfortunately, to err repeatedly is also human.

ALWAYS inform the pilot when there is a similar call sign on the frequency. This will alert the pilots to be particularly careful and will help to reduce the probability of a pilot accepting a clearance intended for another aircraft.

* Taken from an actual ASRS report (Accession Number 190010)

* Taken from an actual ASRS report (Accession Number 169395)

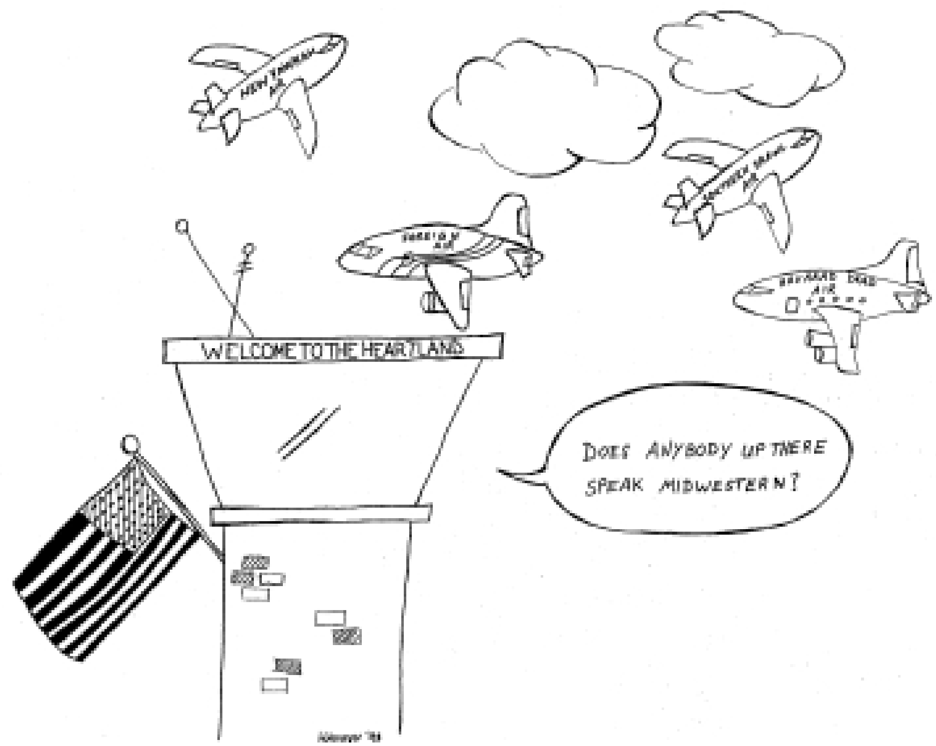
A study of reports submitted to the Aviation Safety Reporting System (ASRS) on pilot-controller communication errors showed that:

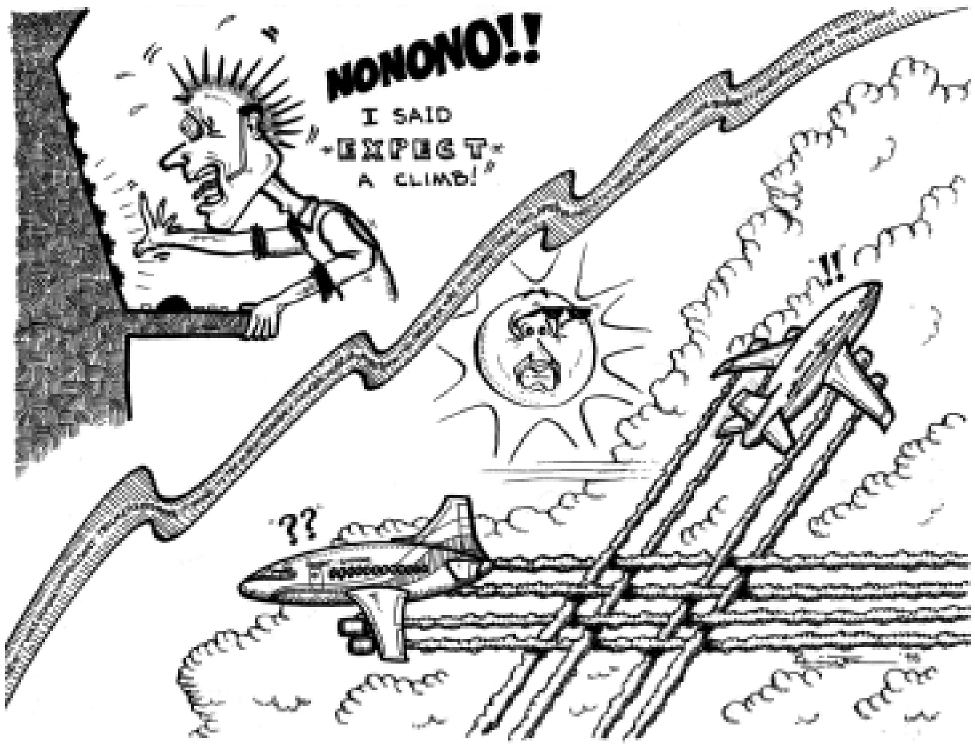
1. Over half (54%) of the reports describing incidents of pilots accepting a clearance intended for another aircraft involved similar call signs.[6]

2. Similar call signs were also identified as a contributing factor in 43% of the reports of communication errors resulting in near mid-air collisions and 21% of the errors resulting in loss of standard separation.[6]

Speaking slowly and distinctly gives any listener a better chance of correctly hearing what was said. However, it is especially important to speak S-L-O-W-L-Y and DISTINCTLY to foreign pilots.

As we speed up our speech rate, we lose many of the cues that help us tell the difference between certain speech sounds. Those cues can mean the difference between understanding the clearance that was issued and needing to ask for a repeat, especially for pilots whose native language is not English.

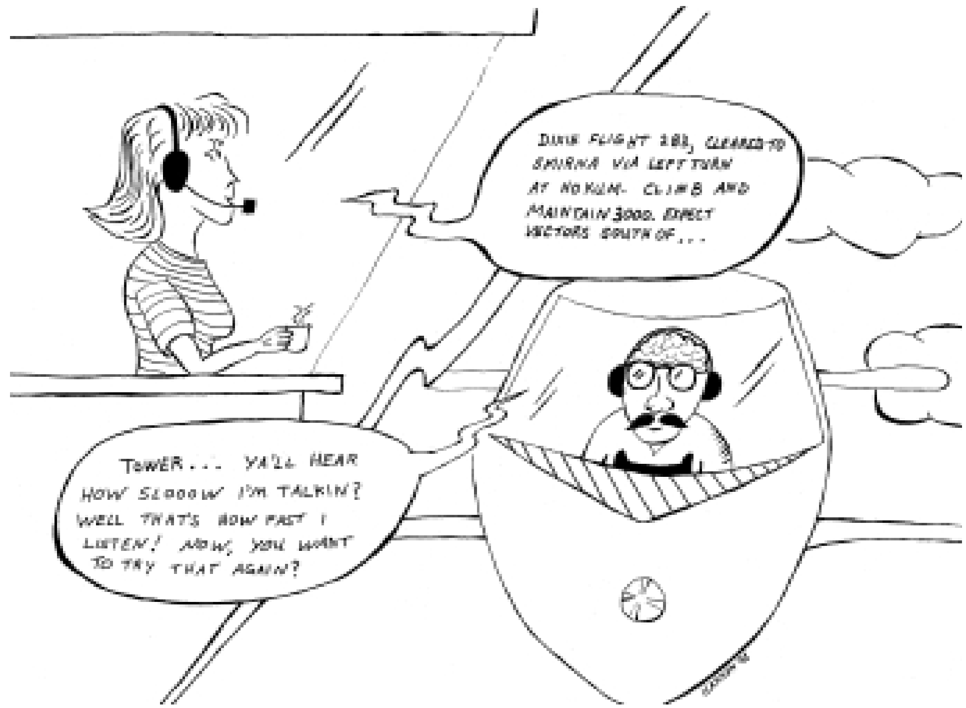




Pilots have been known to interpret what they were told to expect as the actual clearance.

Issue “expect” clearances with caution and emphasize any differences between the actual clearance and what the pilot had been told to expect.

Speaking quickly may seem like a timesaver, but it can backfire. In one simulation study, the rate of pilot read-back errors doubled when the same controller issued the same complex clearances in a moderately faster speaking voice.[11]



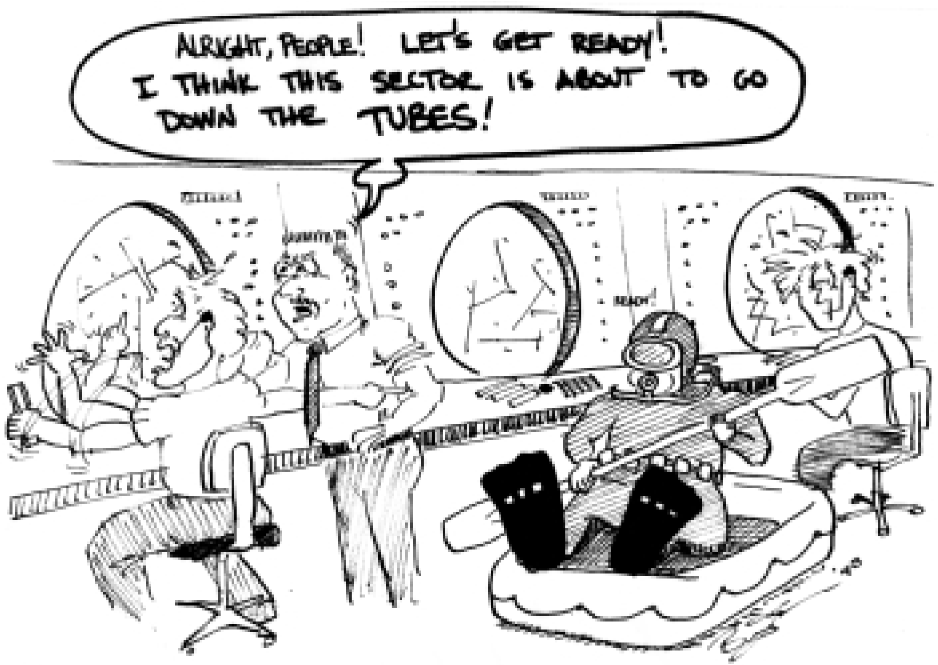
Good microphone technique is critical to prevent clipping call signs; key the transmitter and then pause for a second before speaking.

Even when it's not clipped, we often don't hear the first syllable of a message.

Never issue negative commands (e.g., "Don't climb") and always be sure that the action word in your instruction is what you want the pilot to do.

One of the early developmental versions of TCAS had negative resolution advisories (RAs) such as "Don't Climb" and "Don't Descend". Initial testing in simulators showed that pilots responded inappropriately (such as climbing in response to a "Don't Climb") fifty percent of the time a negative alert was presented.[12] Consequently, all negative RA's were eliminated.

A study of communications in the en route environment showed that maneuvers issued for traffic avoidance took almost twice as long to complete if the controller had to repeat part or all of the clearance. The time from the beginning of the controller's clearance to the end of the pilot's acknowledgment took an average of 19 seconds when a partial or full repeat was required, and nine seconds when the pilot responded correctly to the first transmission. Interestingly, less critical clearances (i.e., turns issued for any other reason but traffic avoidance) took about the same amount of time to successfully transmit. On average, 11 seconds elapsed between the controller's first transmission and the end of the pilot's correct acknowledgment. While things may seem to happen almost instantaneously, in reality, we must plan for these human response times just as we plan for aircraft response times.[13]



Chapter 3

Know Your Limitations: How to Recognize Common Threats to Performance

High workload and stress can induce "tunnel vision", that is, focussing your attention on a small area. Force yourself to scan in a consistent manner to help ensure that no aircraft or situation is forgotten.

Never assume that a pilot will follow the clearance that was issued. Keep up your scan and check.

A study in the United Kingdom found that altitude busts were primarily caused by pilots not complying with ATC vertical clearances which *had been read back correctly.* The study also found that twice as many busts occur during climb as during descent.[14]

Stress impairs memory and makes it easier to forget things. Take time to mentally step back, scan, and assess the situation.

Learn to recognize your own personal signs of stress and those of your colleagues. This may include: talking too fast or too loud, moving close up to the scope, sweating, increased heart rate, or other signals. Remember, air traffic control is a team effort. Call for help before the situation gets out of control.

Treat other controllers as a resource. Encourage their feedback and consider what they have to say.

It's a good idea to inform pilots whenever there is an aircraft in close proximity that the pilot might see, but not expect to see. Good information can go a long way toward preventing faulty perceptions.

In October 1993, a near mid-air collision occurred in Washington Center airspace when a pilot misread his TCAS and descended in front of his traffic. Mistaking "800" for "000", the pilot thought he was at the same altitude as an aircraft that was actually almost 1,000 feet below him.

Chapter 4

Fatigue Busters: Tips for Sleeping Better and Maintaining Alertness on the Job.

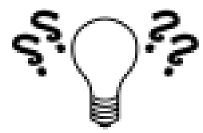
GET ENOUGH SLEEP.

Optimal performance is impossible without adequate sleep. Sleep is necessary for both our physical and psychological well-being. Not getting enough sleep affects memory and our abilities to perform complex tasks (like the planning and problem-solving necessary to predict and resolve conflicts between aircraft).

Working on a schedule that changes constantly presents serious challenges to getting adequate rest. In fact, studies show that while only 15% to 20% of day workers report suffering sleep disturbances, up to 80% of shift workers who work night shifts report this problem.[16]

A critical step in maintaining alertness on the job is getting sufficient quantity and quality of sleep off the job. This means not only getting an adequate amount of sleep (for most people, 7 to 8 1/2 hours), but it also means getting uninterrupted sleep. Interruptions to your sleep reduce the quality of your sleep. Sleep disruptions can also deprive you of the deep stage of sleep. All of this means that even an adequate amount of sleep may not make you feel rested when you wake up; quality is as important as quantity.

Even a small sleep decrement can affect performance. Know your limitations.

Did you know that: 

There is an increase in traffic accidents on the Monday after daylight-saving time begins and a decrease in accidents on the Monday after the return to standard time.[17]

SLEEP BUSTERS:

CAFFEINE

Everyone knows that drinking coffee near bedtime can make it difficult to get to sleep. What you may not know is that caffeine can also disrupt sleep even in people who fall asleep easily after consuming caffeine. For a better night's sleep, avoid caffeine for six hours before bedtime.

SMOKING

Nicotine is a stimulant and cigarette smoking can interfere with sleep.[18]

> "When eight men who had consistently smoked between one-and-a-half and three packs of cigarettes a day for at least two years were persuaded to stop abruptly, they fell asleep faster and woke less during the night, reports Constantin Soldatos, M.D. and his colleagues at Pennsylvania State University. These improvements occurred despite unpleasant daytime effects of (abrupt) cigarette withdrawal..."
> (p. 127).[19]

If you are a smoker who has trouble sleeping, now you have one more reason to quit. And, if you are a smoker who would like to be a non-smoker, see your doctor. There are new and effective ways to help you quit for good.

MORE SLEEP BUSTERS:

ALCOHOL

Drinking alcoholic beverages may help you to fall asleep faster, but it will make the quality of sleep that you get worse than it would have been if you had no alcohol.

LIGHT, HEAT, and NOISE

Sleep in a cool, dark, quiet place. Constant “white noise”, like the hums produced by air conditioners and fans help to cover up other noises, making them less likely to disturb your sleep.

COUCH POTATO LIFESTYLE

A steady exercise program can help improve the quality of the sleep you get by increasing the percentage of time you spend in the restorative deep stage of sleep. Remember, even just one-half hour of moderate exercise three to five times a week can make a remarkable difference in the way you feel.


ISN'T IT A LITTLE LATE IN THE EVENING TO BE DRINKING COFFEE?
NAHH. CAFFEINE DOESN'T AFFECT ME!
3:00

THE PROS AND CONS OF CAFFEINE:

Caffeine can increase vigilance and decrease the feeling of fatigue. It can also postpone sleep (whether you want it to or not), impair the quality of the sleep that you get, and can increase heart rate and blood pressure. It is important to know that caffeine has its peak effects one to three hours after you consume it.

People who have caffeine regularly develop a tolerance to it and eventually need more caffeine to feel the same effect. This makes it more difficult to use caffeine “strategically”, because you will get less of an effect when you need it most.

People who don’t regularly consume caffeine will be more sensitive to its effects (and will find it easier to use caffeine strategically). Sensitivity to caffeine also changes with age so that as we get older, we get more of a “jolt” from the same amount of caffeine.


I DON'T THINK IT REALLY REQUIRES A DEGREE IN PSYCHOLOGY TO KNOW THAT YOU'VE GOT A SERIOUS ADDICTION TO CAFFEINE!

CAFFEINE: WHERE TO FIND IT AND HOW TO AVOID IT

Beverages:

Cup of Coffee - 135 mg per cup.[20] (This can vary widely, however, with the strength of the coffee.)

Tea - 50 mg in 1 cup[1], Instant tea - 30mg in 5 ounces[21]

Coke - 75 mg in 20 ounces[1] , other Colas - 37-45 mg in 12 ounces[20]

Sunkist Orange Soda - 41 mg in 1 cup[20]

Chocolate milk - 5mg in 8 ounces[21]

Water (the bottled caffeinated kind) Aqua Java - 50 to 60 mg in 17 ounces, Krank 2-0 - 100 mg, Java Water - 125 mg[20]

CAFFEINE: WHERE TO FIND IT AND HOW TO AVOID IT

Snacks and Miscellaneous:

Starbucks coffee ice cream - 40-60 mg in 1 cup[20]

Dannon coffee yogurt - 45 mg in 1 cup[20]

Excedrin - 130 mg in 2 tablets, Anacin - 64 mg in 2 tablets[20]

Cascadian Farm Mocha Fudge frozen yogurt - 70mg in 1 cup[22]

Healthy Choice Lowfat Cappuccino Mocha Fudge ice cream - 20 mg in 1 cup[22]

Stonyfield Farm frozen yogurt or ice cream - all coffee or mocha flavors - 0 mg[22]


I REALLY THINK IT'S TIME YOU SWITCHED TO DECAF...

Tips to Maintaining Alertness on the Job:

Now that you know how to get a good night's (or day's) sleep, here are some other tips to help keep you alert on the job:

- Spend break time under bright lights.
- Stand up, stretch, and walk around as much as possible.

Did You Know That:

Wearing sunglasses, eating green leafy vegetables, and not smoking can help protect your eyes by preventing macular degeneration - a leading cause of blindness in people over 55 that affects almost 30% of people over 75.[23,24]

You may see clear or opaque specks or threads that drift across your vision and move with your eyes (these are called "floaters") or flashes of light that aren't really there. These can be perfectly harmless or an indication that a serious problem is developing (such as a tear in the retina). Only your eye doctor can tell the difference. Getting a problem taken care of early is easy and can help save your sight.[25]

Adjusting the brightness on your color monitor will affect color appearance. For example, when the intensity or brightness on the monitor is dimmed, yellow can appear brown, gold, or green.

Certain medications can affect your color vision. For example, Viagra® (sildenafil) can affect the ability to tell the difference between green and blue. For this reason, Dr. Donato Borillo, the Commander of Flight Medicine at Wright-Patterson Air Force Base, recommends that pilots allow at least six hours between taking Viagra and flying.[26] Other drugs can also affect color vision - ask your doctor.

Tower controllers - wearing sunglasses changes the appearance of colors on a monitor and can increase your chances of mistaking one color for another.

Did You Know That...(cont'd)

The appearance of a color can change dramatically when the color is put on a different background. Don't believe it? Look at the illustration on the inside back cover.

Want to protect your hearing? Then stay away from loud noises to guard against "noise-induced hearing loss". Noise-induced hearing loss can be the result of a one-time exposure to an extremely loud noise, repeated exposures to loud noise or extended exposure to moderate noise. This type of hearing loss is usually gradual, painless, and permanent. So turn down the loud music, use a headset instead of a speaker when flying, and wear noise-reducing earplugs when you're using power tools or in a noisy environment. Any sound louder than 80 dB is potentially hazardous.[27] Simply put, if you need to raise your voice to be heard over the noise, then the noise is loud enough to damage your hearing with long-time exposure.

Tinnitus or "ringing in the ears" is the perception of any sound (ringing, buzzing, whistling, etc.) that isn't in the environment. Most people experience it at one time or another.[28] Tinnitus may be a symptom of a problem — such as hearing loss, an ear infection, an obstruction, or other disorder — that requires medical attention.[29] However, it can also be a side-effect of some common medications such as aspirin, ibuprofen (Advil®, Motrin®), certain antibiotics, or alcohol.[29,30] It can also be caused by noise exposure, hypertension, anemia, or stress.[28]

If you wear glasses or contacts and your prescription isn't as strong as it should be, you could be suffering from headaches needlessly. An undercorrection can cause headaches, particularly if you spend a lot of time using a computer screen.

If you are interested in more detail (and I mean a lot more detail) on human factors issues in air traffic control, I recommend the following two publications:

Human Factors in Air Traffic Control by V. David Hopkin, 1995. Published by Taylor & Francis, 1900 Frost Road Suite 101, Bristol, PA 19007. This 479-page book was written for the general public by the "father" of human factors in air traffic control. It includes an introduction to air traffic control and detailed discussions on the topics listed below. Chapter contents are:

1. Historical introduction
2. The air traffic control system
3. The human as a system component
4. Human cognitive capabilities and limitations
5. Matching human and system
6. Air traffic control jobs and tasks
7. Human factors contributions during air traffic control system evolution
8. The selection of controllers
9. The training of controllers
10. The work environment
11. Air traffic control displays
12. Input devices
13. Communications
14. Forms of computer assistance
15. Common human factors implications of computer assistance
16. Effects of the system on the individual controller
17. Conditions of employment
18. Measurement
19. Research and development
20. Human factors implications of other functions related to air traffic control
21. The future

<u>Human Factors in the Design and Evaluation of Air Traffic Control Systems,</u> K. Cardosi and E. Murphy (Eds), 1995. This reference book and checklist (DOT/FAA/RD-95/3) is available on CD to FAA personnel and other air traffic specialists free, while supplies last. This 760-page document (which is why its now on CD) was sponsored by the FAA (AAR-100) and was developed for air traffic controllers who are involved in evaluating, or writing requirements for, new ATC systems. It presents detailed discussions of human factors issues that affect performance and should be considered in equipment/software design and evaluation. Chapter titles are:

1. Introduction
2. Human factors in systems acquisition
3. Visual perception
4. Auditory perception and speech communication
5. Human information processing
6. Issues in ATC automation
7. Computer-human interface (CHI) considerations
8. Workload and performance measurement in the ATC environment
9. Workstation and facility design
10. Human factors testing and evaluation

For a copy of the CD and checklist, contact:
Kim Cardosi, DTS-79
Volpe Center 55 Broadway
Cambridge, MA 02142
cardosi@volpe.dot.gov

REFERENCES

[1]Stein, E., and J. Bailey, 1994. *The Controller Memory Guide: Concepts from the Field.* DOT/FAA/CT-TN94/28.

[2]Morrow, D. and M. Rodvold, 1993. *The Influence of ATC Message Length and Timing on Pilot Communication.* NASA Contract Report 177621.

[3]Cardosi, K. 1993. *An Analysis of En Route Controller-Pilot Voice Communications.* DOT/FAA/RD-94/15.

[4]MiTech Inc., Carlow International Inc., and Federal Aviation Administration's Research and Development Service. *Altitude deviation study: A Descriptive Analysis of Pilot and Controller Incidents.* Final Report, October 1992.

[5]Adam, G.A. and D.R. Kelly, March, 1996. Reports by Airline Pilots on Airport Surface Operations: Part 2. *Identified Problems and Proposed Solutions for Surface Operational Procedures and Factors Affecting Pilot Performance.* MTR94W0000060 V.2 The MITRE Corporation, McLean, Virginia.

[6]Cardosi, K., Falzarano, P., and S. Han, (1998) *Pilot-Controller Communication Errors: An Analysis of Aviation Safety Reporting System (ASRS) Reports.* DOT/FAA/AR-98/17.

[7]Burki-Cohen, J. 1995. An Analysis of Tower (Ground) Controller-Pilot Voice Communications. DOT/FAA/AR-96/19.

[8]Cardosi, K., Brett, B., and S. Han, 1996. *An Analysis of TRACON (Terminal Radar Approach Control) Controller-Pilot Voice Communications.* DOT/FAA/AR-96/66.

[9]Cardosi, K. 1994. *An Analysis of Tower (Local) Controller-Pilot Voice Communications.* DOT/FAA/RD-93/11.

[10]Morrow, D., Lee, A., and M. Rodvold, 1993. Analysis of Problems in Routine Controller-Pilot Communication. *International Journal of Aviation Psychology,* 3(4), 285-302.

[11]Burki-Cohen, J. 1998. *The Effects of Message Complexity, Numerical Format, and Controller Speech Rate on Pilot Readback Errors and Repeats.* Manuscript in Preparation for Publication.

[12]Boucek. G., Pfaff, T., White, W. and W. Smith, March, 1985. *Traffic Alert and Collision Avoidance System - Operational Simulation.* DOT/FAA/PM-85/10.

[13]Cardosi, K. 1993. Time Required for Transmission of Time-Critical/ATC Messages in an En Route Environment. *The International Journal of Aviation Psychology*, 3(4) 303-313.

[14]CAA Analysis Reveals Main Causes of Level Busts (1998). *Air Traffic Management*. September/October Euromoney Publication PLC, London.

[15]Manning, Carol (1998) personal communication.

[16]Rutenfranz, J., Knauth, P., and D. Angersbach, 1981. Shift Work Research Issues. In *The Twenty-Four Hour Workday - Proceedings of a Symposium on Work-Sleep Schedules.* Johnson, L., Texas, W., Colquhoun, W., and M. Colligan, (Eds.). US Government Printing Office OHHS Publication Number NIOSH 81-127: Washington, D.C.

[17]Coren, S. (1996) Daylight Savings Time and Traffic Accidents. *The New England Journal of Medicine*. April 4, 1996 p. 924.

[18]Soldatos, C., Kates, J., and M. Scharf, et. al. 1980. Cigarette Smoking Associated with Sleep Difficulty. *Science*, 207, 551-553.

[19]Lamberg, L. 1984. *The American Medical Association Guide to Better Sleep.* Random House: New York.

[20]*Nutrition Action Newsletter.* July/August, 1997. Center for Science in the Public Interest, Suite 300, 1875 Connecticut Avenue, N.W., Washington, DC 20009.

[21]Dews, P.B., 1984. *Caffeine: Perspectives From Recent Research.* Springer-Verlag: New York.

[22]*Nutrition Action Newsletter.* June, 1998. Center for Science in the Public Interest, Suite 300, 1875 Connecticut Avenue, N.W., Washington, DC 20009.

[23]Hammond, B., Johnson, E., Russell, R., Krinsky, N., Yeum, K., Edwards, R., and D. Snodderly, , 1997. Dietary Modifications of Human Macular Pigment Density. *Investigative Ophthalmology & Visual Science*, 38 (9), 1795 - 1801.

[24]Hammond, B., Wooten, B., and D. Snodderly, (1995). Cigarette Smoking and Retinal Carotenoids: Implications for Age - Related Macular Degeneration. *Vision Research*, 36 (18) pp 3003 - 3009.

[25]American Academy of Opthalmology, 1993. *Floaters and Flashes*. American Academy of Ophthalmology, San Francisco, CA.

[26]Borillo, D. (1998) AMEs Should Become Familiar with the Detrimental Side - Effects of Sildenafil. *Federal Air Surgeon's Medical Bulletin,* Fall.

[27]American Speech-Language-Hearing Association, 1997. *Noise and Hearing Loss.* American Speech-Language-Hearing Association, Rockville, MD.

[28]American Speech-Language-Hearing Association, 1997. *Tinnitus.* American Speech-Language-Hearing Association, Rockville, MD.

[29] *The Merck Manual,* 1982. Merck Co., Inc.: Rahway, N.J., p. 1944.

[30] *Physicians' Desk Reference,* 1995. Medical Economics Data Production Co.: Montvale, N.J., p. 2566.

Other recommended sources:

Hauri, P. *The Sleep Disorders.* 1982. The Upjohn Company. Kalamazoo, Michigan.

Klein, M. 1988. *The Shiftworker's Handbook: A Personal Health and Lifestyle Guide for Shiftwork Professionals.* SynchoTech. 315 S. 9th Street, Suite 211, Lincoln NE 98508.

Monan, W.P., 1986. *Human Factors in Aviation Operations: The Hearback Problem.* NASA Contractor Report 177298.

Monan, W.P., 1983. *Addressee Errors in ATC Communications: The Call Sign Problem.* NASA Contractor Report 166462. National Aeronautics and Space Administration.

Smolensky, M.W. and E.S. Stein, *Human Factors in Air Traffic Control.* Academic Press, New York, 1998.

This is an example of how the color of the background can influence the colors of the foreground. The lines printed on the right are exactly the same as the lines printed within the colored rectangle on the left. (For most people, the lines look grey on the white background, look greenish on the purple background and look purplish on the green background.)

This figure also illustrates how the use of color can change our perception of grouping and space. How many rectangles do you see on the left? How many rectangles do you see on the right? Perceptually, color boundaries can be as effective as lines for defining space.