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Situation Awareness Information Requirements for En Route Air Traffic Control

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SITUATION AWARENESS INFORMATION REQUIREMENTS FOR EN ROUTE AIR TRAFFIC CONTROL

INTRODUCTION

Air traffic control specialists (ATCSs) are called upon to sort-out and project the paths of an ever-increasing number of aircraft in order to ensure goals of minimum separation and safe, efficient take-off, en route and landing operations. This job relies upon the situation awareness (SA) of controllers who must maintain current assessments of the rapidly changing location of each aircraft (in three-dimensional space) and their projected future locations relative to each other, along with other pertinent aircraft parameters (destination, fuel, speed, etc...). Controllers have historically called this "the picture" — their mental model of the situation upon which all of their decisions rely. "The central skill of the controller seems to be the ability to respond to a variety of quantitative inputs about several aircraft simultaneously and to form a continuously changing mental picture to be used as the basis for planning and controlling the course of the aircraft" (Dailey, 1984). Providing controllers with an accurate, complete, and up-to-date picture of the situation may prove to be a daunting challenge as the environment in which they work becomes even more complex and demanding.

While several definitions of SA have been offered, the most generally applicable definition is that provided by Endsley (1987; 1988). "Situation awareness is the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future." A crucial factor in understanding SA in the ATC environment rests on a clear elucidation of the elements in this definition. The objective of this effort was to determine those elements for En Route ATC.

Figure 1 presents a description of SA in relation to decision making and performance. The controller's perception of the elements in the environment, as determined from various displays, readouts, and communications channels forms the basis for situation awareness. The quality of a controller's SA is moderated by his/her capabilities, training and experience, preconceptions and objectives, and ongoing task workload.

Situation awareness forms the critical input to, but is separate from, decision making, which is the basis for all subsequent actions. Proper implementation of rules and procedures will depend on the quality of the controller's SA. Even the best trained and most experienced controllers can make the wrong decisions if they have incomplete or inaccurate SA. Conversely, an inexperienced controller may accurately understand what is occurring in the environment, yet not know the correct action to take. For this reason, it is important that SA be considered separately from the decision making and performance stages. To further expand on the above definition, SA can be described in three hierarchical phases, as depicted in Figure 1.

Level 1 SA - Perception of the elements in the environment

The first phase in achieving SA involves perceiving the status, attributes, and dynamics of relevant elements in the environment. The ATCS needs to accurately perceive each of the aircraft in his/her airspace and their relevant attributes (ID, airspeed, position, route, direction of flight, altitude, etc.), weather, pilot and controller requests, emergency information, and other pertinent elements.

Level 2 SA - Comprehension of the current situation

Comprehension of the situation is based on a synthesis of disjointed Level 1 elements. Level 2 SA goes beyond simply being aware of the elements that are present to include an understanding of the significance of those elements in light of the controller's

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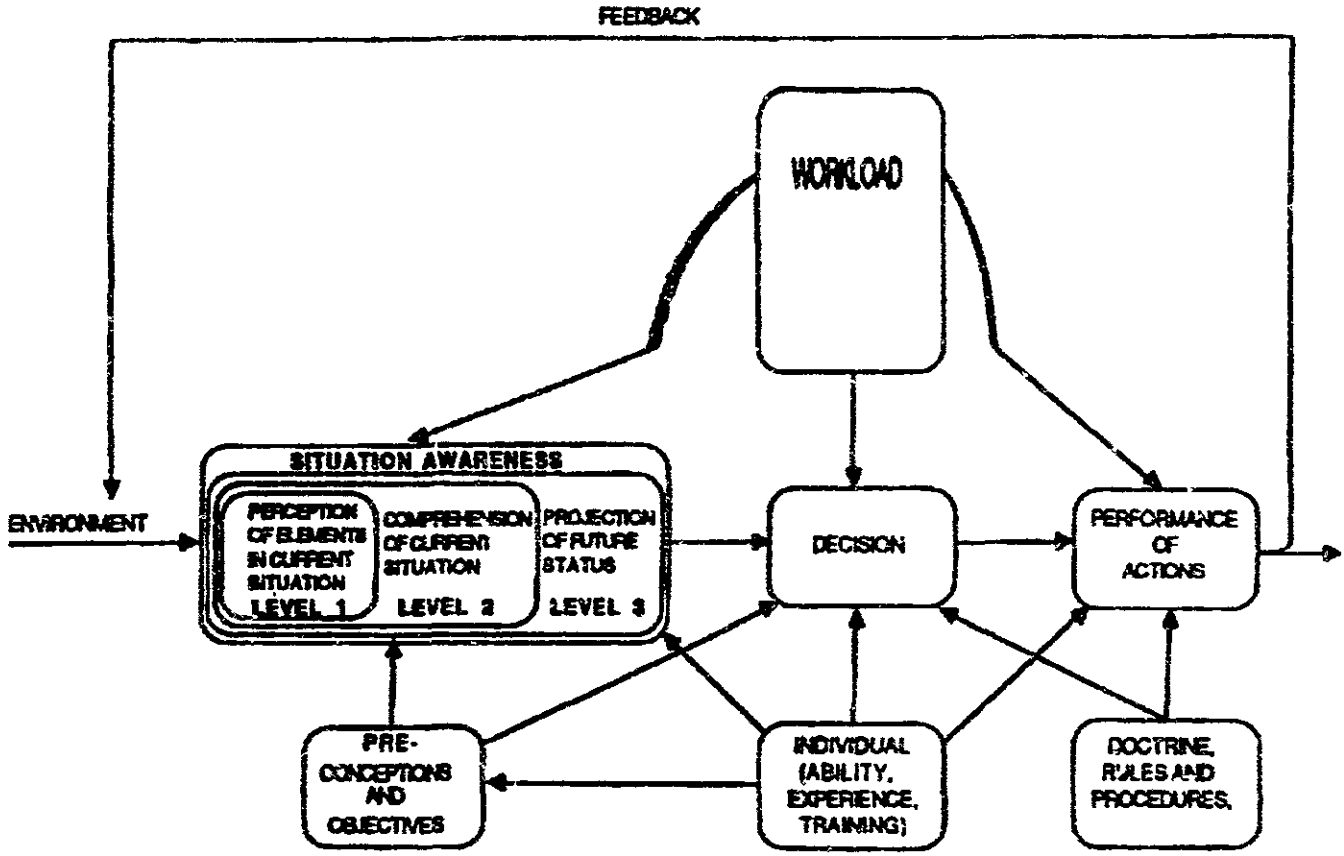

Figure 1. Model of SA in Human Decision Making

goals. Based upon knowledge of Level 1 elements, particularly when put together to form patterns with the other elements, a holistic picture of the environment will be formed, including a comprehension of the significance of objects and events. The controller needs to put together disparate bits of data to determine the impact of a change in one aircraft's flight status on another, or deviations in aircraft positions from expected or allowable values. A novice controller might be capable of achieving the same Level 1 SA as a more experienced one, but may fall short in the ability to integrate various data elements, along with pertinent goals to comprehend the situation, as well.

Level 3 SA - Projection of future status

First it is the ability to project the future actions of the elements in the environment, at least in the near term, that forms the third and highest level of situation awareness. This is achieved through knowledge of the status and dynamics of the elements and a comprehension of the situation (both Level 1 and Level 2 SA). For example, the controller must not only comprehend that three aircraft, given their directions of flight and altitudes, are likely to violate separation rules within a certain period of time, but also determine what airspace will be available to make routing decisions, and ascertain where other potential conflicts may develop. This ability gives the controller the knowledge (and time) necessary to decide on the most favorable course of action.

While SA can be described as the controller's knowledge of the environment at a given point in time, it should be recognized that SA is highly temporal in nature. It is not acquired instantaneously, but is built up over time. Ascertaining aircraft dynamics based on past actions and conditions is part of what allows the controller to project the state of the environment in the near future. It is for this reason that adherence to procedures associated with the position relief briefing is critical. Position relief briefings, involving the use of a checklist, are used to ensure the completeness of information shared. During the briefing, the relief controller typically acquires adequate SA to perform his/her job.

Second, SA is highly spatial in nature in this environment. In addition to a consideration of the spatial relationships between aircraft, the ground, weather patterns, winds, etc..., there is also a spatially-determined and goal-determined specification of just which subsets of the environment are currently important to SA, based on the tasks at hand. ATCSs typically have well-defined spatial boundaries within which their responsibility lies. Within these boundaries, the region may be further subdivided, based on importance to SA. For example, the boundary may shift spatially and temporally to include different aircraft, depending on current goals and tasks, or may shift functionally to include different aspects of aircraft that are being controlled. This subdivision can be dynamically modified as various tasks present themselves by refocusing on different elements within the problem space or by changing the boundaries of the problem space itself.

Within the list of elements that controllers find necessary for good SA, not all elements have equal importance at all times. When conditions are clear, for instance, weather may not be a primary consideration. Controllers may opt to shift attention away from some aircraft to concentrate on a few that are potentially conflicting. It is important to note, however, that elements never become irrelevant or unimportant, just secondary at certain points in time. At least some SA on all elements is required at all times, to know which can be made secondary and which should be primary. And at least some SA is required even on secondary elements in order to know that they have not become primary. Many times it is those elements, deemed as secondary, that cause serious errors when SA on those elements is totally lost. Danaher (1980) reported on a near mid-air collision between a DC-10 and an L-1011, in which the controller was aware of the potential of a traffic conflict between the two jets, yet "became preoccupied with secondary tasks" and failed to monitor the progress of the situation or to report it to the relief controller. Twenty-four people were injured in the resultant evasive maneuver by one of the pilots who managed to avoid a collision at the last minute.

Situation awareness is highly important for successful performance in the demanding ATC environment. Mogford and Tansley (1991) investigated the relationship between controller SA and success in training. They found that SA was positively correlated with performance in an ATC simulator. In a recent study of operational errors, Rodgers and Nye (1993) found that 65 percent of the involved facilities could be classified as having low SA — where the controller was less likely to be aware that a problem was developing. In addition, increased awareness that an error situation was developing was found to be related to a decreased severity of the error.

Rodgers and Nye reported that a high percentage of operational errors can be directly attributed to SA problems. Some 36 percent of the operational errors investigated involved communications errors, with 20 percent specifically involving readback problems. Furthermore, communications problems and readback errors, specifically those involving altitude information, were significantly more likely to be involved in operational errors of a greater severity. This finding agrees with an earlier study by Monan (1986), who found that 78.6 percent of communications errors involved aircrew mishearing ATC clearance/instructions; and 71.5 percent involved an acknowledged failure on the part of the controller to hear the aircrew's error during readback. It should be noted that, considering the total number of communications made, readback problems occur very infrequently.

Rodgers and Nye also found that 57 percent of operational errors investigated could be directly attributed to problems involving the radar display, with 14 percent involving misidentification of information (SA level 1) and 47 percent involving "inappropriate use of displayed data" (SA levels 2 and 3). (Some errors were placed in both categories.) The latter category was more likely to be associated with less severe errors, however, with the exception of conflict alert information, which was directly associated with a higher severity of errors.

Objective & Scope

The objective of this effort was to determine the situation awareness information requirements of the En Route Air Traffic Control Specialist (ATCS), including perception (level 1), comprehension (level 2), and projection (level 3) of elements per the prior definition of SA. These requirements can be used as input to system/equipment design, training, and research and evaluation efforts which need to consider the situation awareness needs of the controller.

Approach

The requirements analysis was performed as a goal-directed task analysis, based on the methodology of Endsley (1993). The SA information requirements were defined as those dynamic information needs associated with the major goals or sub-goals of the controller in performing his or her job. To accomplish this, the major goals of the job were identified, along with the major subgoals necessary for meeting each of these goals. The major decisions associated with each subgoal, that needed to be made, were identified. The SA information requirements for making these decisions and carrying out each sub-goal were then identified. These requirements focused not only on what data the controller needed, but also on how that information was integrated or combined to address each decision. Several caveats need to be mentioned in relation to this analysis.

(1) At any given time, more than one goal or subgoal may be operating, although these will not always have the same priority. The analysis does not assume any prioritization among goals, or that each subgoal within a goal will always be relevant.

(2) The analysis is based on goals or objectives, and was as technology-free as possible. How the information is acquired was not addressed. In some cases, it may be through the radar display, flight progress strips, controller communications with pilots or other controllers, or the controller may have to determine it on his/her own. Many of the higher-level SA information requirements fall into this category.

(3) The analysis sought to determine what controllers would ideally like to know to meet each goal. It is recognized that they often must operate on the basis of incomplete information and that some desired information may not be available with today's system.

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(4) Static knowledge, such as procedures or rules for performing tasks, is outside the bounds of this analysis. The analysis focused only on primarily dynamic situational information that affects what the controllers do.

Methodology

Analysis to determine the SA information requirements for En Route ATCS was comprised of several inter-related activities: (1) analysis and review of the restructured CTA Job Task Taxonomy (Rodgers and Drechsler, 1993) (2) expert elicitation with experienced ATCs, and (3) review and evaluation of videotapes of simulated ATC scenarios.

Task Taxonomy Evaluation

First, the restructured CTA Job Task Taxonomy (Rodgers and Drechsler, 1993) was reviewed to determine major tasks and goals of the ATCS. Information sources and information requirements referred to in the document were determined and listed as possible indications of SA information requirements. The task hierarchy was converted into a diagrammatic form, to achieve a visual representation of an entire task area. The task diagrams and information requirements identified for each task were used to support the second two lines of inquiry (expert elicitation and scenario evaluation).

Expert Elicitation

Eight ATCSs, currently assigned as instructors at the FAA Academy in Oklahoma City, served as subject matter experts, who possessed a broad experience base in En Route ATC, including experience in high, low, ultra-high, arrival and departure sectors, as shown in Table 1. The subjects had an average of 6.2 years of experience as Full Performance Level (FPL) controllers and had, on average, been out of the field for 11.0 months.

Each subject was interviewed individually. In the first session, subjects were provided an introduction to the overall research effort in ATC incident analysis and to the objectives of this project in particular. One or two actual ATC incidents were re-created for them using the Situation Assessment Through the Re-creation of Incidents (SATORI) system (Rodgers and Duke, 1993) to serve as a memory prompt for the ensuing session.

Each subject was interviewed for one-and-a-half hours. During this time, a detailed discussion of one or more major ATC tasks (e.g., separate aircraft, analyze weather) was conducted. The task diagrams and information identified from the Task Taxonomy were used to query the subjects as to: goals, decisions, and processing requirements associated with each task, and thereby, the SA needed for successful completion of each task. Particular attention was paid to

Table 1

Subject Experience

Subject	Years at FPL	Months out of field	Previous assignment
1	4	6	Oakland
2	6	8	Memphis
3	4.5	8	Memphis
4	7	9	Cleveland
5	9	6	Oakland
6	6	19	Houston
7	5	8	Anchorage
8	8	24	Anchorage

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Table 2

En Route ATC SA Requirements

LEVEL 1

Aircraft

- aircraft ID, CID, beacon code
- current route (position, heading, aircraft turn rate, altitude, climb/descent rate, groundspeed)
- current flight plan (destination, filed plan)
- aircraft capabilities (turn rate, climb/descent rate, cruising speed, max/min speed)
- equipment on board
- aircraft type
- fuel/loading
- aircraft status
  - activity (enroute, arriving, departing, handed-off, pointed out)
  - level of control (IFR, VFR, flight following, VFR-on top, uncontrolled object)
  - aircraft contact established
  - aircraft descent established
  - communications (present/ frequency)
  - responsible controller
  - aircraft priority special conditions, equipment malfunctions emergencies
  - pilot capability/state/ intentions
  - altimeter setting

Emergencies

- type of emergency
- time on fuel remaining
- souls on board

Requests

- pilot/ controller requests
- reason for request

Clearances

- assignment given
- received by correct aircraft
- readback correct/ complete
- pilot acceptance of clearance
- flight progress strip current

Sector

- special airspace status
- equipment functioning
- restrictions in effect
- changes to standard procedures

Special Operations

- type of special operation
- time begin/ terminate operations
- projected duration
- area and altitude affected

ATC Equipment Malfunctions

- equipment affected
- alternate equipment available
- equipment position/range
- aircraft in outage area

Airports

- operational status
- restrictions in effect
- direction of departures
- current aircraft arrival rate
- arrival requirements
- active runways/approach
- sector saturation
- aircraft in holding (time, number, direction, leg length)

Weather

- area affected
- altitudes affected
- conditions (snow, icing, fog, hail, rain, turbulence, overhangs)
- temperatures
- intensity
- visibility
- winds
- IFR/VFR conditions
- Airport conditions

LEVEL 2

Conformance

- amount of deviation (altitude, airspeed, route)
- time until aircraft reaches assigned altitude, speed, route/heading

Current Separation

- amount of separation between aircraft/objects/ airspace/ground along route
- deviation between separation and prescribed limits
- number/timing aircraft on route
- altitudes available

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Level 2 (Con't)

Timing

- projected time in airspace
- projected time till clear of airspace
- time until aircraft landing expected
- time/distance aircraft to airport
- time/distance till visual contact
- order/sequencing of aircraft

Deviations

- deviation aircraft/ landing requests
- deviation aircraft /flight plan
- deviation aircraft/pilot requests

Other Sector/Airspace

- radio frequency
- aircraft duration/reason for use

Significance

- impact of requests/ clearances on:
  - aircraft separation/ safety
  - own/other sector workload
- impact of weather on:
  - aircraft safety/ flight comfort
  - own/other sector workload
  - aircraft flow/routing (airport arrival rates, flow rates, holding requirements, aircraft route, and separation procedures)
- altitudes available
- traffic advisories
- impact special operations on sector operations/procedures
- location of nearest capable airport for aircraft type/ emergency
- impact of malfunction on:
  routing, communications, flow control, aircraft, coordination procedures, other sectors, own workload
- impact no. of aircraft on workload
- sector demand vs own capabilities

Confidence Level/ Accuracy of Info

- aircraft ID, position, altitude, airspeed, heading
- weather
- altimeter setting

LEVEL 3

Projected Aircraft Route (Current)

- position, flight plan, destination, heading, route, altitude, climb/ descent rate, airspeed, winds, groundspeed, intentions, assignments

Projected Aircraft Route (Potential)

- projected position *x* at time *t*
- potential assignments

Projected Separation

- amount of separation along route (aircraft/ objects/airspace/ground)
- deviation between separation and prescribed limits
- relative projected aircraft routes
- relative timing along route

Predicted Changes in Weather

- direction/speed of movement
- increasing/decreasing in intensity

Impact of Potential Route Changes

- type of change required
- time and distance till turn aircraft
- amount of turn /new heading, altitude route change required
- aircraft ability to make change
- projected no. of changes necessary
- increase/decrease length of route
- cost/benefit of new clearance
- impact of proposed change on:
  - aircraft separation
  - arrival requirements
  - traffic flow
  - number potential conflicts
  - flow requirements (spacing, timing)
  - aircraft fuel and comfort
  - own/other workload required

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determining the desired form of information, and how that information was used (i.e., the higher-level SA information requirements), which could not be readily determined from available documentation.

Based on the information obtained from the task taxonomy and the subjects, a goal-directed task breakdown was created for each major ATCS goal. This lists the major goals, relevant subgoals, questions to be determined in meeting each subgoal, and first, second-and third- level SA elements required for addressing these questions.

Each of the subjects returned for a second one-and-a-half hour session. At this time, the goal directed task breakdown from the subject's previous session was reviewed with the subject. Necessary corrections and additions to the breakdown were determined by the subject. Additional questions regarding SA information requirements for these tasks were addressed, based on the comments of other subjects and the task taxonomy document. During the second session, initial expert elicitation for the major task area addressed by each of these subjects was completed.

Videotape Analysis

The third line of effort focused on a review of videotaped scenarios of ATCSs performing simulated ATC activities, accompanied by a detailed interview regarding the cognitive processes employed during these tasks. The videotaped simulations and interviews were orginally used for the development of the Human Technology, Inc. cognitive task analysis (HTI, 1990), Seven scenarios (each approximately 30 minutes in length) were reviewed.

This process served to help develop an organizing structure for the task breakdowns by providing insight into the controller's tasks, and as a means of expanding the goal-directed task analysis. The scenarios were evaluated and compared to the task breakdowns developed during expert elicitation. The cognitive processes reported to be employed during the scenarios and the information reported being considered in those processes were determined.

These factors were compared to the task breakdowns to (1) confirm the results of the expert elicitation, and (2) determine tasks, goals, processes, or information requirements that were not derived during expert elicitation. As over-generalizing and summarizing are well known shortcomings of the expert elicitation verbalization processes, the evaluation of these scenarios was important for helping to ensure completeness in the task breakdowns developed.

Final Review

A draft version of the goal-directed task breakdowns for all of the ATCS major goals and tasks was then developed. Next, the draft analysis was circulated to each of the eight subject matter experts for review. They were asked to examine the analysis for completeness and accuracy and make any changes needed. This process allowed each of the subjects to review the document at their leisure, taking into account the SA information requirements of the entire job, and resolving any inconsistencies or language problems. These reviews were then incorporated to form the final SA analysis.

Results & Discussion

From the above procedures, a goal hierarchy, presented in Appendix A, was constructed, which contains the controllers' major goals and subgoals. A listing of the major decision tasks and situation awareness information requirements at all three levels for each subgoal were determined, and are contained in the goal-directed task analysis presented in Appendix B. Considerable overlap is present in situation awareness information requirements between subgoals, as well as a large degree of inter-relatedness between subgoals, as would be expected.

The listing includes many factors that the subjects felt were important to decision making in achieving each of these goals. A careful review of these factors reveals that some are fairly dynamic SA information requirements (e.g., aircraft location, rate of change of altitude), while others are more static (e.g., number of airports, type of special airspace). In addition, some factors did not pertain to the external environment (e.g., one's own fatigue, capabilities).

This list was carefully reviewed to determine those elements that conform to the definition of SA, focusing on dynamic factors within the environment. From this process, a listing of situation

awareness information requirements across subgoals was compiled, and is presented in Table 2. This list includes the controllers' major SA information requirements (for dynamic information), exclusive of static knowledge requirements, sources of the information, or associated tasks. These requirements have been broken down into each of the three levels, perception of elements (level 1), comprehension of their meaning (level 2) and projection of the future (level 3).

This analysis should be useful for guiding the design and development of future ATC systems. An explicit consideration of controller SA information requirements, particularly at the higher levels, should be beneficial for designing more efficient interfaces and suitable automated assistance to ease controller workload and enhance SA in the performance of their tasks. In addition, this list of SA information requirements can be used to direct SA measurement efforts as they pertain to ATC system design evaluation, training technique evaluation, error investigation, or construct exploration.

References

Dailey, J. T. (1984). Characteristics of the air traffic controller. In S. B. Sells, J. T. Dailey, and E. W. Pickerel (Eds.), *Selection of air traffic controllers* (pp. 128-141). Washington, D. C.: Federal Aviation Administration, Office of Aviation Medicine.

Danaher, J. W. (1980). Human error in ATC system operations. *Human Factors*, 22(5), 535-545.

Endsley, M. R. (1987). *SAGAT: A methodology for the measurement of situation awareness* (NOR DOC 87-83). Hawthorne, CA: Northrop Corporation.

Endsley, M. R. (1988). Design and evaluation for situation awareness enhancement. *Proceedings of the Human Factors Society 32nd Annual Meeting* (pp. 97-101). Santa Monica, CA: Human Factors Society.

Endsley, M. R. (1993). A survey of situation awareness requirements in air-to-air combat fighters. *International Journal of Aviation Psychology*, 3(2), 157-168.

Human Technology, Inc. (1990). *Cognitive task analysis of prioritization in air traffic control.* McLean, Virginia. October 1990. Under Contract OPM-87-9041.

Mogford, R. H., and Tansley, B. W. (1991). *The importance of the air traffic controller's mental model.* Paper presented at the Human Factors Society of Canada Annual Meeting, Canada.

Monan, W. P. (1986). *Human factors in aviation operations: The hearback problem* (NASA Contractor Report 177398). Moffett Field, CA: NASA Ames Research Center.

Rodgers, M. D., and Duke, D. A. (1993). SATORI: Situation assessment through the re-creation of incidents. *Journal of Air Traffic Control*, 35(4), 10-14.

Rodgers, M. D., and Nye, L. G. (1993). Factors associated with the severity of operational errors at Air Route Traffic Control Centers. In M. D. Rodgers (Ed.), *An analysis of the operational error database for Air Route Traffic Control Centers* (DOT/FAA/AM-93/22) Washington, DC: Federal Aviation Administration, Office of Aviation Medicine.

Rodgers, M. D., and Drechsler, G. K. (1993). *Conversion of the CTA, Inc., En Route operations concepts database into a formal sentence outline job task taxonomy* (DOT/FAA/AM-93/1). Washington, DC: Federal Aviation Administration, Office of Aviation Medicine.

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Appendix A
Goal Hierarchy

0. Assure flight safety

1. Avoid conflictions
   - 1.1. Separate aircraft
     - 1.1.1 Assess aircraft separation
     - 1.1.2 Resolve aircraft conflict
       - 1.1.2.1 Determine required change
       - 1.1.2.2 Assess aircraft conformance (1.3.1)
     - 1.1.3 Issue traffic advisory

   - 1.2. Avoid airspace conflict
     - 1.2.1 Assess aircraft/airspace separation
     - 1.2.2 Resolve airspace conflict
       - 1.2.2.1 Determine conflict resolution method
       - 1.2.2.2 Avoid airspace
       - 1.2.2.3 Obtain/give airspace release
       - 1.2.2.4 Issue aircraft advisory
     - 1.2.3 Accept hand-off/point-out
       - 1.2.3.1 Impact on aircraft safety
       - 1.2.3.2 Impact on own workload
       - 1.2.3.3 Impact on sector workload
       - 1.2.3.4 Type of coordination/contact needed
     - 1.2.4 Initiate hand-off/provide point-out
       - 1.2.4.1 Assess need for hand-off or point-out
       - 1.2.4.2 Coordinate hand-off or point-out

   - 1.3. Maintain aircraft conformance
     - 1.3.1 Assess aircraft conformance to assigned parameters
     - 1.3.2 Resolve non-conformance

   - 1.4. Assure minimum altitude requirements
     - 1.4.1 Assess altitude safety
     - 1.4.2 Change altitude

2. Provide flight service

   - 2.1.1 Projected aircraft route (current)
   - 2.1.2 Aircraft capabilities
   - 2.1.3 Aircraft status
   - 2.1.4 Projected aircraft route (potential)

2.2. Provide clearance
- 2.2.1 Assess potential clearance changes
  - 2.2.1.1 Impact on own workload
  - 2.2.1.2 Impact on other sector workload
  - 2.2.1.3 Impact on traffic flow/separation
  - 2.2.1.4 Impact on aircraft/flight
- 2.2.2 Assess aircraft separation (1.1.1)
- 2.2.3 Assess aircraft/airspace separation (1.2.1)
- 2.2.4 Assure minimum altitude requirements (1.4)
- 2.2.5 Issue clearance
- 2.2.6 Document clearance
  - 2.2.6.1 Perform coordination
  - 2.2.6.2 Update flight plan

2.3. Manage arrivals
- 2.3.1 Establish arrival sequence
  - 2.3.1.1 Sequence aircraft
  - 2.3.1.2 Adjust aircraft airspeed, altitude, heading
  - 2.3.1.3 Provide clearance (2.2)
  - 2.3.1.4 Maintain aircraft conformance (1.3)
- 2.3.2 Provide holding pattern
  - 2.3.2.1 Initiate holding pattern
  - 2.3.2.2 Establish holding pattern
  - 2.3.2.3 Remove from holding
  - 2.3.2.4 Provide clearance (2.2)
- 2.3.3 Establish aircraft landing

2.4. Manage departure flows
- 2.4.1 Locate departing aircraft
- 2.4.2 Get aircraft on route and at altitude
- 2.4.3 Provide clearance (2.2)
- 2.4.4 Separate aircraft (1.1)
- 2.4.5 Maintain aircraft conformance (1.3)

2.5. Process flight following requests
- 2.5.1 Assess request
  - 2.5.1.1 Ability to provide flight following
  - 2.5.1.2 Impact on own workload
  - 2.5.1.3 Impact on aircraft
- 2.5.2 Assess aircraft separation (1.1.1)
- 2.5.3 Assess aircraft/airspace separation (1.2.1)
- 2.5.4 Assure minimum altitude requirements (1.3)

2.6. Relieve/assume control
- 2.6.1 Assess sector
- 2.6.2 Assess airport status
- 2.6.3 Assess aircraft separation (1.1.1)
- 2.6.4 Assess aircraft/airspace separation (1.2.1)
- 2.6.5 Assure minimum altitude requirements (1.4)
- 2.6.6 Assess weather impact (3.1)

2.7. Manage information
- 2.7.1 Remove information
- 2.7.2 Request information
- 2.7.3 Modify/record information

3. Handle perturbations

3.1. Assess weather impact
- 3.1.1 Determine if action is needed
  - 3.1.1.1 Weather impact
  - 3.1.1.2 IFR/VFR conditions
  - 3.1.1.3 Flight levels available
  - 3.1.1.4 Airport conditions
- 3.1.2 Provide clearance (2.2)

3.2. Respond to emergencies
- 3.2.1 Emergency detection
- 3.2.2 Determine special handling requirements

3.3. Assess equipment malfunction
- 3.3.1 Determine problem
- 3.3.2 Establish alternate procedures
- 3.3.3 Establish maintenance release

3.4. Handle special operations

3.5. Determine impending workload
- 3.5.1 Own capabilities
- 3.5.2 Sector demands

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APPENDIX B
GOAL DIRECTED TASK ANALYSIS - EN ROUTE AIR TRAFFIC CONTROL

The goal directed task analysis lists each of the controller's main goals, associated subgoals and situation awareness information requirements for meeting these subgoals. The format of the document is as follows:

X.X Goal (Associated task taxonomy ID (Rodgers and Drechsler, 1993))
- X.X.X Subgoal
  - *questions to be answered to meet the goal*
    - SA information requirements (high level)
      - SA information requirements (low level)

There are few guidelines that should be kept in mind when reviewing this document.

- At any given time more than one goal or subgoal may be operating, although these will not always have the same priority. The attached listing does not assume any prioritization among them, or that each subgoal within a goal will always come up.

- These are goals or objectives, not tasks. The analysis is supposed to be as technology free as possible. How the information is acquired is not addressed. In some cases it may be through the radar display, the flight progress strips, communications, other controllers, or the controller may have to determine it on his or her own or guess. Many of the higher level SA information requirements may fall into this category. This analysis does not address how a controller would get the information or problems with information overload.

- The analysis sought to define what controllers would ideally like to know to meet each goal. It is recognized that they often must operate on the basis of incomplete information and that some desired information may not be available at all with today's system.

- Static knowledge, such as procedures or rules for performing tasks, is also outside the bounds of this analysis. The analysis primarily identifies dynamic situational information that affects what controllers do.

1.0 Avoid Conflictions

1.1 **Separate aircraft** (1A 1-5,13,15) (IIA) (III F)

- 1.1.1 Assess aircraft separation
  - vertical separation meets or exceeds limits?
  - vertical distance between aircraft along route (projected)
    - vertical distance between aircraft (current)
      - aircraft altitude (current)
      - altitude accuracy
      - altitude (assigned)
      - altitude rate of change (climbing/descending)

- *lateral separation meets or exceeds limits?*

will aircraft cross?
will aircraft overtake?
time until convergence?

- lateral distance between aircraft along route (projected)
- lateral distance between aircraft (current)
  - aircraft position
  - **projected aircraft route (current) (2.1.1)**
  - **aircraft capabilities (2.1.2)**
- *Separation with uncontrolled objects meets or exceeds limits?*
  - lateral distance between aircraft and object (current)
  - vertical distance between aircraft and object (current)
    - *aircraft position*
    - **projected aircraft route (current) (2.1.1)**
    - **object position**
    - **projected object route (current) (2.1.1)**

1.1.2 Resolve aircraft conflict

1.1.2.1 Determine required change

- *which aircraft to move?*
- *lateral change, speed change or vertical change?*
  - projected impact on traffic
  - projected number of changes necessary
  - projected paths
    - **Relative projected aircraft routes (current)**
      - vertical distance between aircraft along route
      - horizontal distance between aircraft along route
      - relative timing along route
        - **projected aircraft route (current) (2.1.1)**
    - **Relative projected aircraft routes (potential)**
      - vertical distance between aircraft along route
      - horizontal distance between aircraft along route
      - relative timing along route
        - projected aircraft route (potential)
        - projected position *x* at time *t*
          - **projected aircraft route (current) (2.1.1)**
          - assigned altitude (potential)
            - assigned airspeed (potential)
            - assigned heading (potential)
            - assigned route (potential)
    - level of control
    - actions taken on aircraft
    - pilot capabilities
    - **assess weather impact (3.1)**
    - **aircraft capabilities (2.1.2)**

1.1.2.2 Assess aircraft conformance (1.3.1)

1.1.3 Issue traffic advisory
- *Aircraft in proximity?*
  - Level of control
  - **Assess aircraft separation**

1.2 Avoid airspace conflict (I A 6,8) (II C) (III C) (IV I,H) (VI H)

1.2.1 Assess aircraft/airspace separation
- *potential airspace violation?*
- *airspace to be avoided?*
  - projected position of aircraft relative to airspace
  - current position of aircraft relative to airspace
    - aircraft ID
    - **projected aircraft route (current) (2.1.1)**
    - **aircraft capabilities (2.1.2)**
    - airspace
      - who's in control
        - current status
        - normal activation period
    - boundaries
    - altitude limits
    - type

1.2.2 Resolve airspace conflict

1.2.2.1 Determine conflict resolution method
- *Best method?*
  - impact on aircraft
    - degree of change from route required to avoid airspace
    - ability of aircraft to alter vector or altitude to avoid airspace
    - projected position of aircraft relative to airspace
    - aircraft priority
    - special conditions
  - impact on own workload
    - amount of coordination required
      - number of coordinations with aircraft to complete
      - number of coordinations with controlling agency to complete
  - impact on traffic flow/aircraft separation
    - **assess aircraft/airspace separation (1.2.1)**
    - **assess aircraft separation (1.1.1)**
- *Release available?*
  - hand-off acceptance
  - point-out acceptance

1.2.2.2 **Avoid airspace**

- *time and distance till turn aircraft?*
- amount of turn or new heading required?
- *amount of altitude change required?*
  - projected position of aircraft relative to airspace
  - current position of aircraft relative to airspace
    - aircraft ID
    - **projected aircraft route (current) (2.1.1)**
    - **projected aircraft route (potential)**
      - projected position *x* at time *t*
        - **projected aircraft route (current) (2.1.1)**
        - assigned altitude (potential)
        - assigned airspeed (potential)
        - assigned heading (potential)
        - assigned route (potential)
    - **aircraft capabilities (2.1.2)**
    - airspace
      - boundaries
      - altitude limits
  - Assess aircraft conformance (1.3.1)

1.2.2.3 **Obtain/give airspace release (III G,H)**

- *type of coordination /contact needed?*
  - airspace hand-off & point out procedures
  - aircraft hand-off designation
  - airspace
    - controlling agency/facility
    - type of airspace
    - frequency
  - **projected aircraft route (current) (2.1.1)**
- *release available?*
  - impact on aircraft separation
    - **Assess aircraft separation (1.1.1)**
- impact on workload
  - duration of use
  - purpose of use
  - aircraft ID
  - time until aircraft clear of airspace
  - requesting/controlling organization
- **projected aircraft route (current) (2.1.1)**

1.2.2.4 Issue aircraft advisory
- *advisory needed?*
- *advisory possible?*
  - projected aircraft position relative to airspace
    - **Assess aircraft/airspace separation (1.2.1)**
    - aircraft ID
    - level of control

1.2.3 Accept hand-off/point-out (IV F,G)
- *ability to safely accept aircraft?*

1.2.3.1 impact on aircraft safety
- **assess aircraft separation (1.1.1)**
- **assess aircraft/airspace separation (1.2.1)**
- **assure minimum altitude requirements (1.4)**

1.2.3.2 impact on own workload
- number of aircraft in sector
- number of potential conflicts
  - **assess aircraft separation (1.1.1)**
  - **assess aircraft/airspace separation (1.2.1)**
- amount of coordination required
  - other sectors impacted
  - number of coordinations with aircraft to complete
    - **projected aircraft route (current) (2.1.1)**
    - **aircraft capabilities (2.1.2)**
    - sector boundaries

1.2.3.3 impact on other sector workload
- number of aircraft in sector
- number of potential conflicts
  - **assess aircraft separation (1.1.1)**
  - **assess aircraft/airspace separation (1.2.1)**
- amount of coordination required
  - other sectors impacted
  - number of coordinations with aircraft to complete
    - **projected aircraft route (current) (2.1.1)**
    - **aircraft capabilities (2.1.2)**
    - sector boundaries

1.2.3.4 type of coordination/contact needed
- hand-off, point-out procedures in effect
- hand-off, point-out request
- sector requesting

- *contact established?*
  - aircraft position
  - aircraft ID
  - communications present
  - altimeter setting correct

1.2.4 Initiate hand-off/ provide point-out (IV H,I)

1.2.4.1 Assess need for hand-off or point out

- *will aircraft enter airspace?*
- *will aircraft skim airspace?*
- *for how long?*
  - projected position of aircraft relative to airspace
    - **Assess aircraft/airspace separation (1.2.1)**

1.2.4.2 Coordinate hand-off or point-out

- *hand-off/point-out accepted?*
- *aircraft notified?*
  - type of coordination /contact needed
  - airspace hand-off & point out procedures
  - aircraft hand-off designation
  - airspace
    - controlling agency/facility
    - type of airspace
    - frequency

1.3 Maintain aircraft conformance (I A 7,9) (III B)

1.3.1 Assess aircraft conformance to assigned parameters

- *aircraft at/proceeding to assigned altitude?*
- *aircraft proceeding to assigned altitude fast enough?*
  - time until aircraft reaches assigned altitude
  - amount of altitude deviation
  - climb/descent
    - altitude (current)
    - altitude (assigned)
    - altitude rate of change (ascending/descending)
- *aircraft at/proceeding to assigned airspeed?*
- *aircraft proceeding to assigned airspeed fast enough?*
  - time until aircraft reaches assigned airspeed
  - amount of airspeed deviation
    - airspeed (indicated)
    - airspeed (assigned)
    - groundspeed
- *aircraft on /proceeding to assigned route?*
- aircraft proceeding to assigned route fast enough?

- *aircraft turning?*
  - time until aircraft reaches assigned route/heading
    - amount of route deviation
      - aircraft position (current)
      - aircraft heading (current)
      - route/heading (assigned)
    - aircraft turn rate (current)
    - aircraft heading (current)
    - aircraft heading (past)
    - aircraft turn capabilities
      - aircraft type
      - altitude
    - aircraft groundspeed
    - weather
    - winds (direction, magnitude)

1.3.2 Resolve non-conformance

- *Reason for non-conformance?*
  - Verify data
    - *Is presented altitude correct?*
      - Aircraft altimeter setting
      - Aircraft altitude (indicated)
    - *Is presented airspeed correct?*
      - Aircraft airspeed (indicated)
      - groundspeed
      - winds (magnitude, direction)
  - *Is presented position/heading correct?*
    - Fix distance to Nav aid
    - range/bearing to Fix
    - track code
  - *Will current behavior cause a problem?*
    - **Assess aircraft separation (1.1.1)**
    - **Assess aircraft/airspace separation (1.2.1)**
    - **Assure minimum altitude requirements (1.4)**
  - Action to bring into conformance?
    - **Provide clearance (2.2)**

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1.4 Assure minimum altitude requirements (II B)

1.4.1 Assess altitude safety

- *aircraft within limits?*
- *change possible?*
  - minimum altitude in area
    - obstructions
    - terrain
    - minimum safe altitude
    - minimum IFR altitude
    - **projected aircraft route (current) (2.1.1)**
    - **aircraft capability (2.1.2)**
  - level of control

1.4.2 Change altitude

- *change needed?*
  - provide clearance (2.2)

2.0 Provide Flight Service

2.1 Assess Aircraft Status

- *Who is it?*
- *Where is it going ?*
- *What is it doing ?*
- *What can it do?*
- *What do I need to do?*
  - aircraft ID (call sign)
  - CID
  - altimeter setting

2.1.1 projected aircraft route (current)

- position
- current flight plan (requested route, altitude)
- destination
- heading (current)
- heading (assigned)
- route (assigned)
- altitude (actual)
- altitude (assigned)
- altitude rate of change (ascending/descending)
- airspeed (indicated)
- airspeed (assigned)
- groundspeed
- winds (direction, magnitude)
- pilot intentions
- **Assess weather impact (3.1)**

2.1.2 aircraft capabilities

- **turn rate**
  - climb/descent rate
  - cruising speed
  - max/min speed
  - equipment on board
  - aircraft type
  - fuel/loading
  - temperature/dewpoint
  - destination

2.1.3 aircraft status

- activity (enroute, arrival airport, departure airport, handed-off, pointed-out)
- level of control (IFR, VFR, VFR-flight following, VFR-on top, uncontrolled object)
- responsible controller
- pilot capability/state
- aircraft priority
  - special conditions
  - equipment malfunctions
  - emergencies
- actions taken on aircraft (assignments/coordinations)
- confidence level of information

2.1.4 Projected aircraft route (potential)

- projected position *x* at time *t*
  - **projected aircraft route (current) (2.1.1)**
  - assigned altitude (potential)
  - assigned airspeed (potential)
  - assigned heading (potential)
  - assigned route (potential)

2.2 Provide clearance (I B) (IV A)

2.2.1 Assess potential clearance changes

- *Is new clearance beneficial?*
  - cost/benefit of new clearance

    2.2.1.1 Impact on own workload
    - number of aircraft in sector
    - number of potential conflicts
      - **assess aircraft separation (1.1.1)**
      - **assess aircraft/airspace separation (1.2.1)**
      - projected aircraft route (potential) (2.1.4)

- amount of coordination required
  - other sectors impacted
  - *number of coordinations with aircraft to complete*
  - aircraft ease in getting to new route
  - aircraft ease in getting to destination with new route
    - projected aircraft route (potential) (2.1.4)
    - aircraft capabilities (2.1.2)
    - sector boundaries

2.2.1.2 Impact on other sector workload

- number of aircraft in sector
- number of potential conflicts
  - *assess aircraft separation (1.1.1)*
  - assess aircraft/airspace separation (1.2.1)
    - projected aircraft route (potential) (2.1.4)
- amount of coordination required
  - other sectors impacted
  - number of coordinations with aircraft to complete
    - projected aircraft route (potential) (2.1.4)
    - aircraft *capabilities (2.1.2)*
    - sector boundaries

2.2.1.3 Impact on traffic flow/separation

- Assess aircraft/airspace separation (1.2.1)
- Assess aircraft separation (1.1.1)
- Assure minimum altitude requirements (1.4)
  - projected aircraft route (potential) (2.1.4)
- Impact on flow requirements
  - aircraft spacing
  - aircraft timing
  - aircraft routes
    - arrivals
    - departures
  - projected aircraft route (potential) (2.1.4)

2.2.1.4 Impact on aircraft/flight

- Reason for change
  - emergency
  - weather
  - special conditions
  - traffic
- aircraft priority
- aircraft capabilities (2.1.2)
- pilot capabilities
- impact on fuel, flight comfort
  - increase/decrease in length of route of flight
  - Assess weather impact (3.1)

2.2.2 Assess aircraft separation (1.1.1)
- projected aircraft route (potential) (2.1.4)

2.2.3 Assess aircraft/airspace separation (1.2.1)
- projected aircraft route (potential) (2.1.4)

2.2.4 Assure minimum altitude requirements (1.4)
- projected aircraft route (potential) (2.1.4)

2.2.5 Issue Clearance (IV J)
- *clearance received & accepted?*
  - clearance received by correct aircraft
    - aircraft ID
  - clearance repeated correctly and completely
    - new heading
    - new altitude
    - new airspeed
    - new route
  - pilot acceptance
  - projected aircraft route (potential) (2.1.4)

2.2.6 Document clearance (IV D) (IV E)

2.2.6.1 Perform coordination
- *need for coordination with another sector?*
- *sectors impacted?*
  - projected aircraft route (current) (2.1.1)
  - flight plan changes/corrections/info
    - new heading
    - new altitude
    - new airspeed
    - new route
    - special conditions
  - sector boundaries
- best method for coordination?
  - Impact on own workload
  - Impact on other sector workload
    - number of coordinations required
    - coordination procedures available

2.2.6.2 Update flight plan

- projected aircraft route (current) (2.1.1)
- flight plan changes/corrections/info
- new heading
- new altitude
- new airspeed
- new route
- special conditions
- pilot reports
- controller actions taken

2.3 Manage arrivals

2.3.1 Establish arrival sequence (III D)

2.3.1.1 Sequence aircraft

- *who's in front?*
- *who's number one?*
  - Relative projected aircraft routes (current)
    - vertical distance between aircraft along route
    - horizontal distance between aircraft along route
    - relative timing along route
      - projected aircraft route (current) (2.1.1)
  - Aircraft capabilities (2.1.2)
  - pilot capabilities
  - aircraft priority
    - special conditions
    - equipment malfunctions
    - emergencies

2.3.1.2 Adjust aircraft airspeed, altitude, heading

- *amount/type of change required?*
- *ability of proposed change to meet arrival requirements?*
- *impact of proposed change on aircraft separation?*
- *impact of proposed change on own workload requirements?*
  - Deviation between aircraft and landing requirements
    - Establish arrival requirements
      - airport operational status
      - airport acceptance airspeed, altitude, spacing, route, active approach
      - airport conditions (3.1.1.5)
      - flow restrictions
      - aircraft in holding
      - sector saturation
  - Projected aircraft route (current) (2.1.1)
  - Aircraft capability (2.1.2)
  - Relative projected aircraft routes (current)
    - vertical distance between aircraft along route
    - horizontal distance between aircraft along route

- relative timing along route
  - projected aircraft route (current) (2.1.1)

- **Relative projected aircraft routes (potential)**
  - vertical distance between aircraft along route
  - horizontal distance between aircraft along route
  - relative timing along route
    - **projected aircraft route (potential)**
    - projected position x at time t
      - **projected aircraft route (current) (2.1.1)**
      - assigned altitude (potential)
      - assigned airspeed (potential)
      - assigned heading (potential)
      - assigned route (potential)
- **Assess aircraft separation (1.1.1)**

2.3.1.3 Provide clearance (2.2)

2.3.1.4 Maintain aircraft conformance (1.3)

2.3.2 Provide holding pattern

2.3.2.1 Initiate holding pattern

- *exceed arrival rate limits?*
  - aircraft arrival rate
    - **Relative projected aircraft routes (current)**
      - vertical distance between aircraft along route
      - horizontal distance between aircraft along route
      - relative timing along route
        - **projected aircraft route (current) (2.1.1)**
  - airport arrival rate limits

2.3.2.2 Establish holding

- *altitude to assign?*
- *expected time in holding?*
- *length of holding pattern leg?*
  - aircraft altitude
  - altitudes available
  - aircraft arrival rate
    - **Relative projected aircraft routes (current)**
      - *vertical distance between aircraft along route*
      - *horizontal distance between aircraft along route*
      - *relative timing along route*
        - **projected aircraft route (current) (2.1.1)**
  - airport arrival rate limits
  - number of aircraft in holding

2.3.2.3 Remove from holding

- other aircraft landed
- aircraft altitude (current)
- aircraft priority
  - special conditions
  - equipment malfunctions
  - emergencies
- time in holding
- pilot requests

2.3.2.4 Provide clearance (2.2)

2.3.3 Establish aircraft landing (I C)

- *aircraft landed?*
  - time until aircraft landing expected
    - destination
    - time/position descent started
    - last known position
    - type of approach
  - aircraft arrival notice received

2.4 Manage departure flows (III E)

2.4.1 Locate departing aircraft (I C) (IV L)

- *Aircraft position?*
  - departure point
  - departure direction
    - assigned heading
    - assigned turns
  - time of departure
  - position
  - aircraft ID
  - aircraft track code
    - beacon code
    - aircraft movement
    - radar target

2.4.2 Get aircraft on route and at altitude

- *route or altitude changes needed?*
  - deviation between aircraft and plan
  - deviation between aircraft and request
    - Departure flows (airspeed, altitude, spacing, route)
      - number/timing of aircraft on each route
        - active runways
        - restrictions in effect
        - airport operational status
      - assess weather impact (3.1)

- **Relative projected aircraft routes (current)**
  - vertical distance between aircraft along route
  - horizontal distance between aircraft along route
  - relative timing along route
    - **projected aircraft route (current) (2.1.1)**
- Aircraft ID
- Flight plan (filed)
  - requested altitude
  - requested route
  - destination
- requested aircraft route
- requested aircraft altitude
- Next available altitude
- **Assess weather impact (3.1)**

2.4.3 Provide clearance (2.2)

2.4.4 Separate aircraft (1.1)

2.4.5 Maintain aircraft conformance (1.3)

2.5 Process flight following request (I D)

2.5.1 Assess request

- *grant request?*
  - **Ability to provide flight following**
    - *In my airspace?*
      - projected aircraft route (current) (2.1.1)
      - sector boundaries
      - radar coverage areas
  - **Impact on own workload**
    - number of aircraft in sector
    - number of potential conflicts
      - **Assess aircraft/airspace separation (1.2.1)**
      - **Assess aircraft separation (1.1.1)**
    - amount of coordination required
      - number of coordinations with aircraft to complete
        - aircraft ID
        - **projected aircraft route (current) (2.1.1)**
        - **aircraft capabilities (2.1.2)**
        - special conditions
        - pilot capabilities
        - aircraft priority
          - special conditions
          - equipment malfunctions
          - emergencies
        - aircraft activity

- impact on aircraft
  - reason
    - Assess weather impact (3.1)
    - Respond to emergency (3.2)
      - Need for traffic advisories
      - pilot capabilities
      - *pilot intentions*
      - number of potential conflicts
        - Assess aircraft/airspace separation (1.2.1)
        - Assess aircraft separation (1.1.1)

2.5.2 Assess aircraft separation (1.1.1)

2.5.3 Assess aircraft/airspace separation (1.2.1)

2.5.4 Assure minimum altitude clearance (1.3)

2.6 Relieve/assume control (VI A,B)

- *actions to be taken?*
- *own workload?*
- *other sector workload?*

2.6.1 Assess sector

- coordination requirements/status
  - aircraft handed-off/to whom
  - aircraft near boundaries
  - aircraft point-outs
  - frequency changes made
  - coordination actions taken
- Assess aircraft status (2.1)
- special airspace
  - current status
  - boundaries
  - altitude limits
  - type
  - controlling agency
- equipment functioning
  - nav aids
  - radar
  - frequencies
- restrictions in effect (flow control, altitude, speed, adjacent sectors)
- hand-off procedures in effect
- flight progress strips up-to-date

2.6.2 Assess airport status

- operational?
  - weather
  - hours of operation
- direction of departures
  - active runways
- acceptance rate
- restrictions in effect
- **airport conditions (3.1.1.5)**
- aircraft with airport destination
  - time/distance to airport
- arrival requirements
  - active approach
    - runway in use
  - airspeed
  - altitude
  - route
  - spacing
  - restrictions in effect
- sector saturation
- holding problems

2.6.3 Assess aircraft separation (1.1.1)

2.6.4 Assess aircraft/airspace separation (1.2.1)

2.6.5 Assure minimum altitude requirements (1.4)

2.6.6 Assess weather impact (3.1)

2.7 Manage information

- *needed information present, readable, updated?*
- *clutter minimized?*

2.7.1 Remove information

- flight cancellation
- aircraft rerouted out of sector
- clutter
- aircraft leaves sector, handed-off, frequency changed
- aircraft cancels IFR, flight following

2.7.2 Request information

- no datablock
- no FPS
- information incomplete

2.7.3 Modify/record information

- overlapping datablocks
- actions taken, planned
- changes to aircraft (clearances, status, equipment, weather, special operations)
- coordinations made

3.0 Handle perturbations

3.1 Assess weather impact (V A,B)

3.1.1 Determine if action is needed

- *deviation needed?*
- *advisory needed ?*
- *adjust altitude/lateral separation procedures?*

3.1.1.1 Weather impact

- impact on aircraft
- impact on aircraft flight comfort
- impact on own workload
- impact on other sector workload
- impact on aircraft flow/routing
  - weather area
    - area affected
    - altitudes affected
    - conditions
      - snow
      - icing
      - fog
      - turbulence
      - hail
      - rain
      - overhangs
    - temperatures
    - intensity
    - visibility
    - turbulence
      - altitudes, area
    - predicted changes in weather
      - direction/speed of movement
      - increasing/decreasing in intensity
    - confidence level of information
  - winds
    - direction
    - magnitude
    - gusts
    - variance
    - wind shear
  - projected aircraft route (current) (2.1.1)
  - aircraft capabilities (2.1.2)

3.1.1.2 IFR/VFR conditions

- time/distance required for visual contact
  - visibility
  - sun position
  - light available
  - fog, clouds

3.1.1.3 Flight levels available

- altimeter settings
- turbulence

3.1.1.4 Airport conditions

- *determine need to hold aircraft?*
- *adjustment to airport arrivals ?*
  - runways open
  - snow/ice
  - breaking action
  - aircraft climb rate
    - dew point
    - temperature
  - altimeter settings
  - visibility

3.1.2 Provide clearance (2.2)

3.2 Respond to emergencies (IV B)

- *actions needed?*
- *actions taken?*

3.2.1 Emergency detection

- loss of aircraft communications
- loss of radar coverage
- route/altitude deviation
- pilot emergency declaration
- type of emergency
- Assure minimum altitude requirements (1.4)
- establish aircraft landing (2.3.5)

3.2.2 Determine special handling requirements

- type of emergency
- pilot requests
- pilot capabilities/state
- aircraft ID
- aircraft capabilities (2.1.2)
- projected aircraft route (current) (2.1.1)
- time on fuel remaining
- souls on board
- location of nearest airport with capabilities for aircraft type and type of emergency
- coordination required

3.3 Assess equipment malfunctions

3.3.1 Determine problem

- equipment affected (radar, comm, NAVAID, BUEC, DARC, scope, aircraft)

3.3.2 Establish alternate procedures

- impact of malfunction on communications, flow control, routing, coordination procedures
- impact on other sectors
  - alternate equipment available
  - position of facility, range of coverage
- impact on aircraft
  - aircraft affected
  - equipment on board
  - alternate equipment available
  - position of facility, range of coverage
  - projected aircraft route (current) (2.1.1)
- equipment affected (radar, comm, NAVAID, BUEC, DARC, scope, aircraft)

3.3.3 Establish maintenance release

- *release OK?*
  - impact on own workload
  - traffic needing facility (projected)
    - special operations
    - projected traffic load
  - alternate equipment available
  - impact on aircraft
    - aircraft affected
    - equipment on board
    - alternate equipment available
    - position of facility, range of coverage
    - projected aircraft route (current) (2.1.1)
  - Assess weather impact (3.1)

3.4 Handle special operations (IV c)

- *changes to s.o.p. needed?*
  - impact on sector operations
  - type of special operation (military operations, air show, recreational activity, etc...)
  - time begin and terminate operations
  - projected duration
  - area and altitude affected

3.5 Determine impending overload (VI F)

- *Do I need help?*
- *Do I need flow control adjustments?*
  - Ratio of demands to capabilities

    3.5.1 Own capabilities
    - own fatigue
    - own stress
    - own ability
      - length of time on sector
      - breaks (duration, time since)
      - experience level
      - currency and proficiency
      - personal endurance level
      - cyclical factors (time since last shift)
      - sleep
      - emotional stress
      - health
      - personal attitudes
      - degree of trust in and cooperation with other controllers (D side, relieving controller, adjacent sector controller)

    3.5.2 Sector demands
    - traffic complexity
      - number of aircraft
      - number of arrivals and departures
      - emergencies
      - aircraft activity (en route, inbound - airport, outbound - airport, hand-offs, point-outs)
      - level of control (IFR, VFR, VFR-flight following, VFR- on top, uncontrolled)
      - number of pilot requests
      - number of clearance changes
      - pilot capabilities
    - sector complexity
      - layout
      - low/high altitude
      - number of airports
      - number of set-ups required
      - terrain
      - flow requirements
      - number of crossing airways
    - outages
    - Assess weather impact (3.1)

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