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PILOT'S AUTOMATED WEATHER SUPPORT SYSTEM (PAWSS) CONCEPTS DEMONSTRATION PROJECT

PHASE I - PILOT'S WEATHER INFORMATION REQUIREMENTS AND IMPLICATIONS FOR WEATHER DATA SYSTEMS DESIGN

April 1991

Interim Report
(Phase I - Findings)

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16. Abstract
This report defines the weather information requirements for pilots, and deficiencies of the current aviation weather support system in meeting these requirements. As the amount of data available to pilots increases significantly in the near future, expert system technology will be needed to assist pilots in assimilating that information. Some other desirable characteristics of an automation-assisted system for weather data acquisition, dissemination and assimilation are also described.

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1.0 INTRODUCTION

"...today's airline pilot finds him/herself highly challenged to determine an optimum routing during hazardous weather. High emphasis is placed on a pilot's ability to accurately determine the effects of adverse weather on his or her intended route of flight." (Massey, 1989). This challenge of planning and conducting flight operations during adverse weather extends to all classes of aviation and to all categories of pilots.

The National Weather Service and the Federal Aviation Administration have on-going long-range programs to improve the aviation weather data acquisition, analysis, and dissemination systems (Tomlinson 89, and FAA 87). These programs are already increasing the quantity of data readily available to the pilot and will, in the future, provide even more and higher quality weather observations and forecasts. With these increases, it is becoming apparent that more attention needs to be paid to exactly what weather data pilots actually need, how it will be provided, and how it will be displayed. Thus Sprinkle, 1989, states that "...the detection and warning phases...are somewhat more in hand...than the final dissemination of that vital product..." and McCarthy, 1989, concludes that "...in a revolutionized weather [information] system, we must bring weather hazard forecast, detection, and warning to a point where pilot decision-making takes weather completely into account... At the very least, decision-making in the cockpit must he aided by expert system computers that reduce flight options to several clear cut choices..."

The current definition of the pilots' weather information requirements is contained in the FAA's Aviation Weather System Plan (AWSP), 1985. This document indicates that the inflight pilots' needs are met by 1) ground radio voice broadcasts 2) ground radio voice replies to voice radio requests by the inflight pilot, and 3) in the future by the Mode S Request Reply Data Link System. Since the AWSP was published, other uplink systems which provide weather support have appeared. These include 1) the ACARS Request/Reply system for displaying alphanumeric weather data discussed in McCarthy, 1986; 2) a commercially available broadcast system for displaying a single ground weather radar map via an FM subcarrier uplink (*Aviation Consumer*, 1987), and 3) a system for providing NWS graphics in the cockpit via a facsimile link through an airborne telephone (*Flying*, 1988). Further, in August 1990, the FAA convened a Future System Design Working Group to develop a high-level description of the future air traffic management system (ATM). In their report, the group noted that the FAA's current modernization efforts... "do not fully address the need for and the possibilities for enhanced aviation weather services in such areas as:... the dissemination of weather products tailored to the particular needs of National Airspace System (NAS) end users... and that the direct dissemination of weather information to users will be an increasingly important objective of the future weather system, with emphasis on air/ground data link." (FAA 90). These recent developments and the FAA's proposed future air traffic management system are all responding to a real and pressing need for cockpit display of near real-time alphanumeric and graphical weather information.

In the future, any cockpit weather display system will have access to much more data as noted above. Because of the expected volume and value of such data, future systems should consider methods of providing the relevant data to the cockpit on an automatic basis, with little effort required by the pilot, and should display the data in operationally oriented parameters that relate directly to the decisions the pilot makes in flight. Ultimately, expert system technology should be applied to aid the pilot in assimilating these data.

This report examines the pilot decision-making process for each phase of a flight, identifies the weather data needed, how they are used, and provides a systematic definition of the pilots' weather information requirements. This report also compares these weather data requirements with the capabilities of the current system, and indicates an approach to the definition of an automation-assisted weather information system to provide the necessary weather information to the pilot.

2.0 PILOT WEATHER INFORMATION NEEDS

The specific weather data requirements for each aircraft operation depend on many factors, including the type of aircraft, the route, the planned flight profile, the pilot capabilities, and the expected weather. In this paper, however, the weather information requirements for the conduct of aircraft flight operations have been defined in a generic sense by analyzing a typical flight profile. A scenario has been defined for which a Flight Plan has been created, flight progress has been compared against that plan, and replans have been indicated as necessary. This analysis can be applied to all modes of aircraft operations, from the flight of short-range low-altitude helicopters, to flights of small general aviation fixed-wing aircraft, to large intercontinental jet transport operations. The amount of data required and the timing in obtaining it will vary widely for these various modes, with consequent impacts on the way the pilot needs to get the data and the efforts required to interpret and react to it in the conduct of the flight. However, the result can serve as a guide for defining the pilot's weather information requirements, for determining limitations of the current aviation weather information system, and for indicating some desirable characteristics of the future system.

2.1 DETAILED ANALYSIS

The generic flight profile used in this analysis is presented in figure 1. Although simplified, it is comprised of 12 phases, including operations to an alternate airport. The analysis scenario has been developed to illustrate the effect of the availability of weather information on the pilot's decision-making process and consists of the following procedure:

1. develop the flight plan, considering the anticipated effect of weather on, (a) the aircraft performance, (b) the crew capabilities, (c) the crew and passenger safety and comfort,

2. perform each phase,

3. monitor the performance in each phase including the effects of the actual weather and any new forecasts,

4. replan that phase and any subsequent phases as required.

Inherent in this scenario is the very real dichotomy between the requirement that the flight be planned based on the forecast, while the actual flight is in fact conducted on the pilot's understanding of the actual weather as it unfolds. The results of the analysis are presented in figures 2 through 8 in the form of flow charts which identify for each phase of flight activity, the meteorological data required, the current weather information system products in which the type of required data is available as defined in the FAA's Aviation Weather Services description, AC 00-45C, and a detailed statement of the deficiencies inherent in those products or the need for additional products. It is interesting to note that the preflight planning and flight plan development activities require more than two pages of the seven page flow chart. This is due to the need, in some cases, to examine large amounts of weather data to establish the creditability of the forecast, or to obtain/establish a revised forecast when needed, and to perform necessary aircraft performance trade-offs to determine the conditions under which the flight can be legally and practically accomplished.

Most airline, commuter and upper-end business aircraft operations have a flight dispatch or contract weather service to provide the required weather data to the aircrew while most general aviation operations do not have such individual weather support. In adverse weather situations, pilots of all classes of aviation (from general aviation to commercial airlines) can spend much time in acquiring and evaluating the required weather data, both preflight and inflight.

The charts presented in figures 2 through 8 only illustrate the top level considerations in the pilot's decision making process. The next level of detail can be found in many excellent references such as the FAA's: Aviation Weather; Buck's: Weather Flying; Collins': Flying IFR; the various airline's operations manuals, or the related military directives or publications. Nevertheless, these flow charts illustrate the decision-making process involved in flight planning and flight operations, how these decisions are affected by the availability of weather information, and provide a logical definition of the weather information requirements for pilots.

The weather information requirements and deficiencies defined in the detailed flow charts have been summarized in figure 9 for each phase of a typical flight.

3.0 DEFICIENCIES OF THE CURRENT SYSTEM

Comparison of the requirements defined in section 2 above with the capabilities of the present FAA aviation weather information system reveals that much of the weather data, analyses, and systems support required are not available from today's system, including:

1. Surface observations and terminal forecasts at many airports. Such airports can not be used as destinations in Part 121 and 135 operations, or as Alternates in Part 91, 121 or 135 operations.

2. Adequate runway, taxiway, and runup area condition reports at many airports. These are usually only available from PIREPS. If no aircraft has landed or departed there recently, PIREPS are not available.

3. ATIS information from many airports that have instrument approaches.

4. Accurate descriptions of present weather aloft elements away from airports, i.e., in large terminal areas, and especially enroute, including;

   a. Real time observations and accurate forecasts of cloud layer bases, tops, and lateral extent. Currently, these data are available only at airports with surface observations; enroute, data is from PIREPS or Area Forecasts. Area Forecasts do not consider small-scale effects which could make routes unusable for VFR.

   b. Real time observations and accurate forecasts of winds aloft. Currently wind data is provided from forecasts which are usually many hours old, and do not reflect small-scale and short term changes. Winds between the surface and the first forecast level are not available at all.

   c. Real time observations and accurate forecasts of icing locations and severity, in a form that can be used by pilots to estimate the effect on their specific type of aircraft. Current forecasts are too general in severity, and too broad in location and time. PIREPS help, but are scarce, and if not for the same type of aircraft, serve only as a warning.

   d. Real time observations and accurate forecasts of turbulence in a form that can be used by pilots to estimate aircraft response. The problems with the current situation are similar to those noted for icing in "c" above.

e. Real time observations and accurate forecasts of hazardous weather that is below the available ground weather radar coverage along the approach and departure paths in large terminal areas.

5. Quick comparison of how the actual weather is developing along the route compared with the forecast conditions. Weather briefers can provide these evaluations. Current and projected reliance on preflight self-briefings, however, through company dispatch "weather board" displays or alpha-numeric printouts such as the Direct User Access Terminal (DUAT) system require considerable time and effort by the pilot. Inflight support normally requires pilot initiated requests with only limited, abbreviated information available.

6. Real time forecast guidance when the official forecast is wrong and amendments have not yet been issued, including winds aloft. Without timely amendments or easy, reliable access to aviation meteorologists, pilots are forced to rely on their own estimates.

7. A user-friendly way of getting the large amount of information, when needed, to the pilot in real time. The problems with the current situation are similar to those noted in "5" above.

8. Easily understood display formats and expert system procedures for assimilating this large amount of information in real time. In the present system, the time needed to manually assimilate large amounts of data in a rapidly changing situation may well require most of the time between hourly weather updates; thus creating a possible safety hazard. Further, the present system does not allow easy inflight application and integration of weather updates into flight management systems.

These limitations of the present system indicate that, under "bad weather conditions", it is not possible to acquire and assimilate sufficient information to properly plan and execute some flights. Some examples include: 1) operations without access to trained meteorologists/briefers for comparing the actual weather over the route of flight with the forecast weather to validate the forecast before flight; 2) VFR-only operations planning without adequate information defining cloud layer bases, tops, and lateral extent along the proposed route; 3) non-commercial IFR operations conducted into airports that have no surface observations nor terminal forecasts; 4) inflight operations in rapidly changing unforecast weather conditions. This last condition not only applies to general aviation operations, but also to air carrier operations. When a major air carrier hub gets backed-up due to unforecast weather, the company dispatch function quickly becomes seriously overloaded by too many simultaneous requests for weather data, and the air carrier pilots are unable to get enough weather information onboard to permit an orderly modification to the flight plan. This creates major traffic problems for air traffic control and major logistics problems for the airline and passengers.

Accordingly, operational procedures have been developed to cope with these and other short comings. These procedures sometimes result in flights that are not attempted when they could be flown, or that can not be completed as planned, with consequent loss of efficiency and utilization of the aircraft as a transportation system; in unwanted effects on the air traffic control system; and in some cases, in accidents that result in property damage, personnel injuries, or fatalities. Also, many aircraft use on-board sensors such as weather radar and lightning detectors to indicate the presence of hazardous convective areas in the enroute phase. These systems provide a degree of protection for thunderstorm avoidance, but do not provide any information on clouds, visibility or icing locations.

4.0 IMPLICATIONS FOR FUTURE SYSTEMS

It has already been discussed, in section 1.0, that as the NWS program for observing and analyzing the weather matures and more data become available, and as the communication capability of the FAA data dissemination system evolves, the total amount of data that the pilot has to contend with will increase significantly. Some means must be provided to aid the pilot in processing and assimilating this increasingly large amount of data. Clearly, what is needed is a system that will provide the pilot, inflight as well as in preflight planning, with a continuously up-dated assessment of the actual and expected weather that can affect the flight in a form that is easy to acquire and use. It is proposed that a state-of-the-art automation-assisted weather observing, communications and processing system be developed to provide this needed weather data directly to the pilot in near real-time in a user-friendly form. The requirements for such a system include:

1. all pertinent observations be automated to provide a fine scale time resolution of rapidly changing weather events,

2. these automated observing systems be located with a geographic spacing capable of detecting the existence of small scale events,

3. this information be communicated automatically and continuously, directly to a data base on-board the aircraft,

4. on-board weather observations be automatically integrated into the onboard data base,

5. displays describing the actual and forecast weather along the route be automatically derived from the data in the onboard data base,

6. the displays be oriented to the needs of the pilot in making operational decisions as they are affected by weather,

7. the validity of the forecast be determined by automatically comparing the actual weather with the forecast weather, and when necessary, suitable guidance products be automatically generated,

8. expert system technology be used to monitor this information and to generate alerts and four dimensional flight path recommendations for the pilot in real time.

Such a system could also speed up the preflight planning process outlined in section 2 above.

5.0 CONCLUDING REMARKS

The weather information requirements for pilots have been defined in a systematic way for all phases of flight operations. These results indicate that due to the large volume of data that could be required to apprise pilots of all weather factors that could affect their flight, there will be a need for a highly automated acquisition, analysis and dissemination system, with expert system support, to assist pilots in assimilating that information. The FAA is supporting research initiatives for providing such automation-assistance support to pilots through the Pilot's Automated Weather Support System (PAWSS) Concepts Development Project. (Dash & Crabill, 1991).

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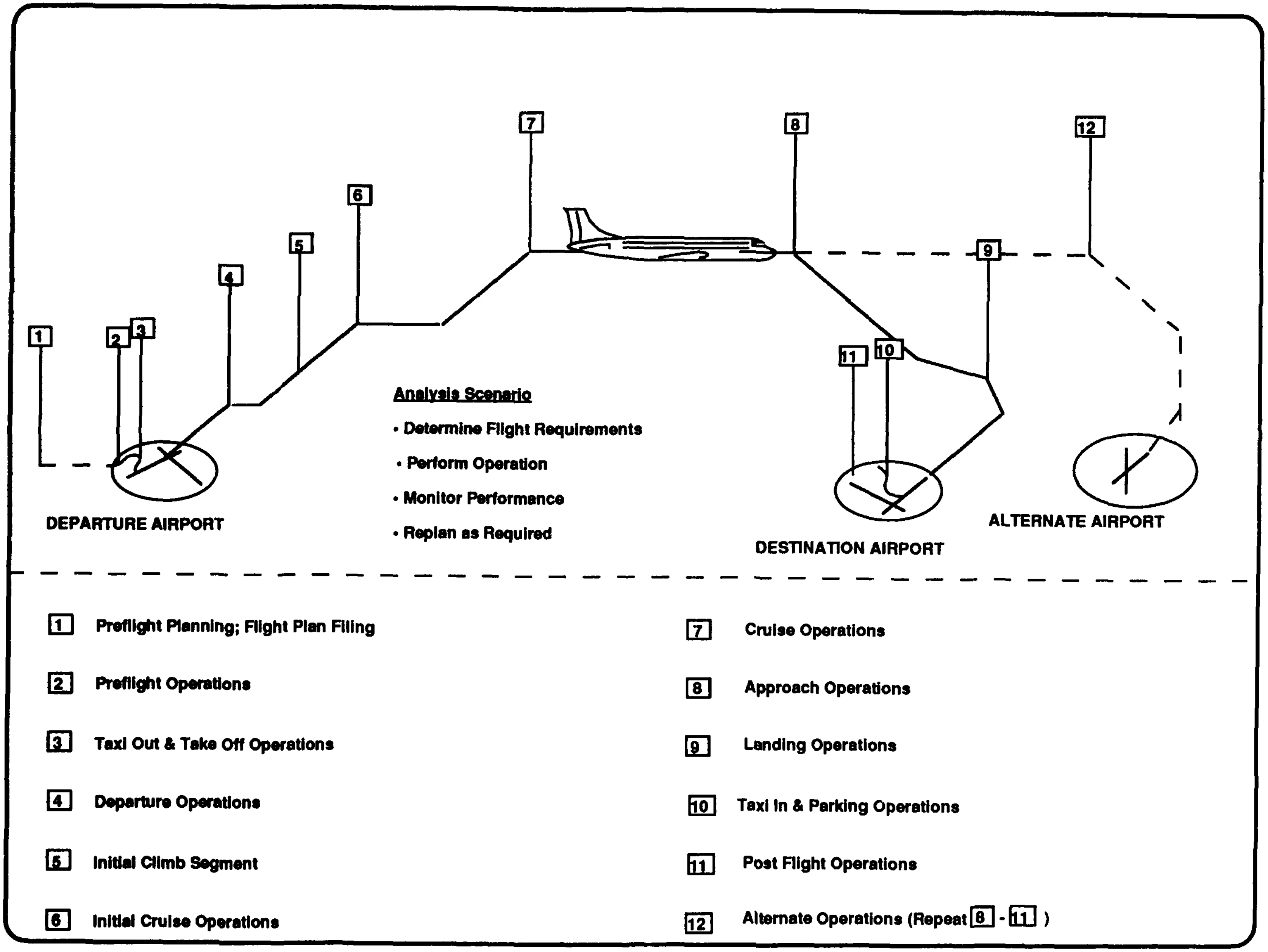

Figure 1 Generic Operation Profile and Analysis Scenario

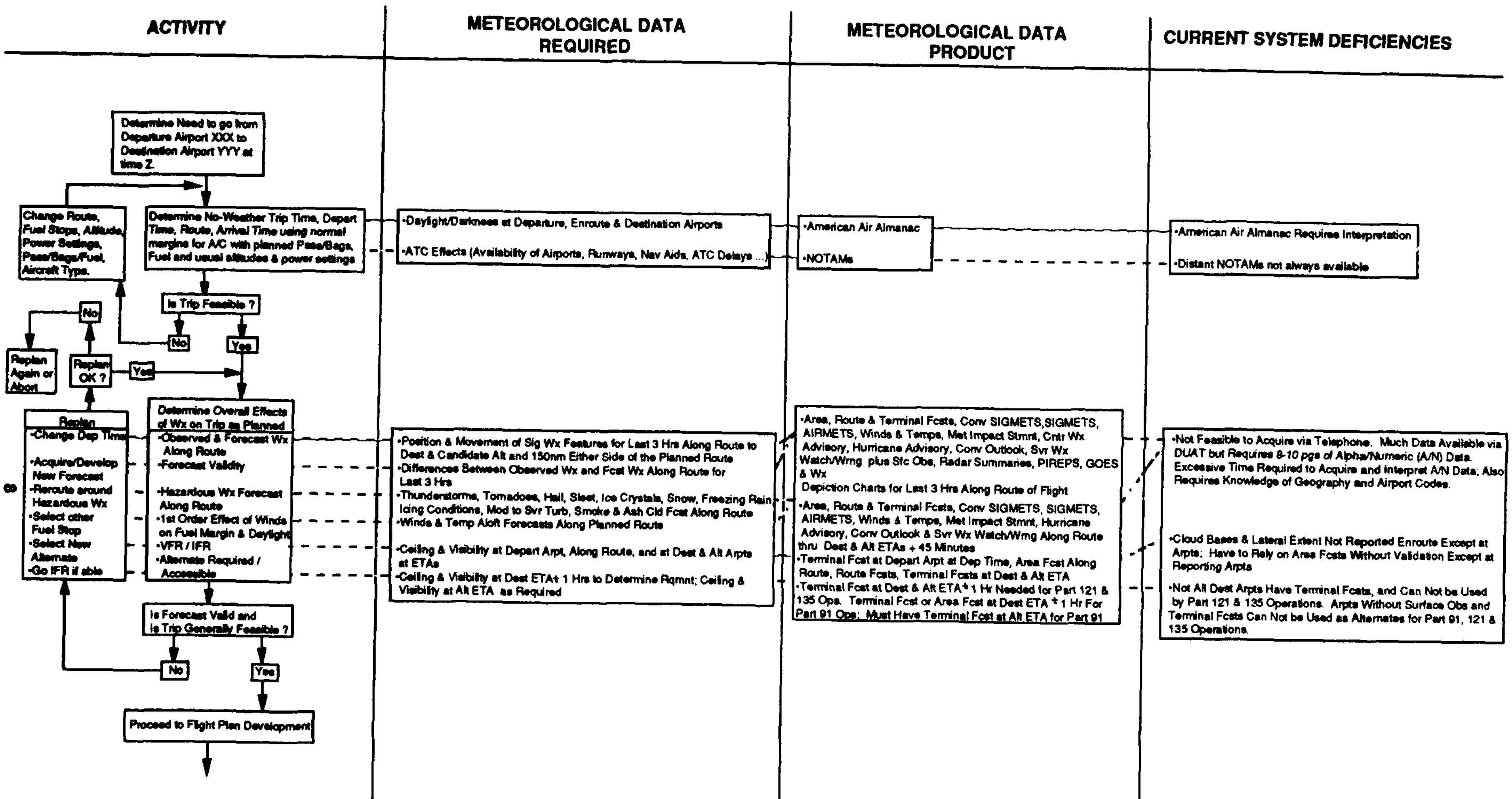

Figure 2. Preflight Planning

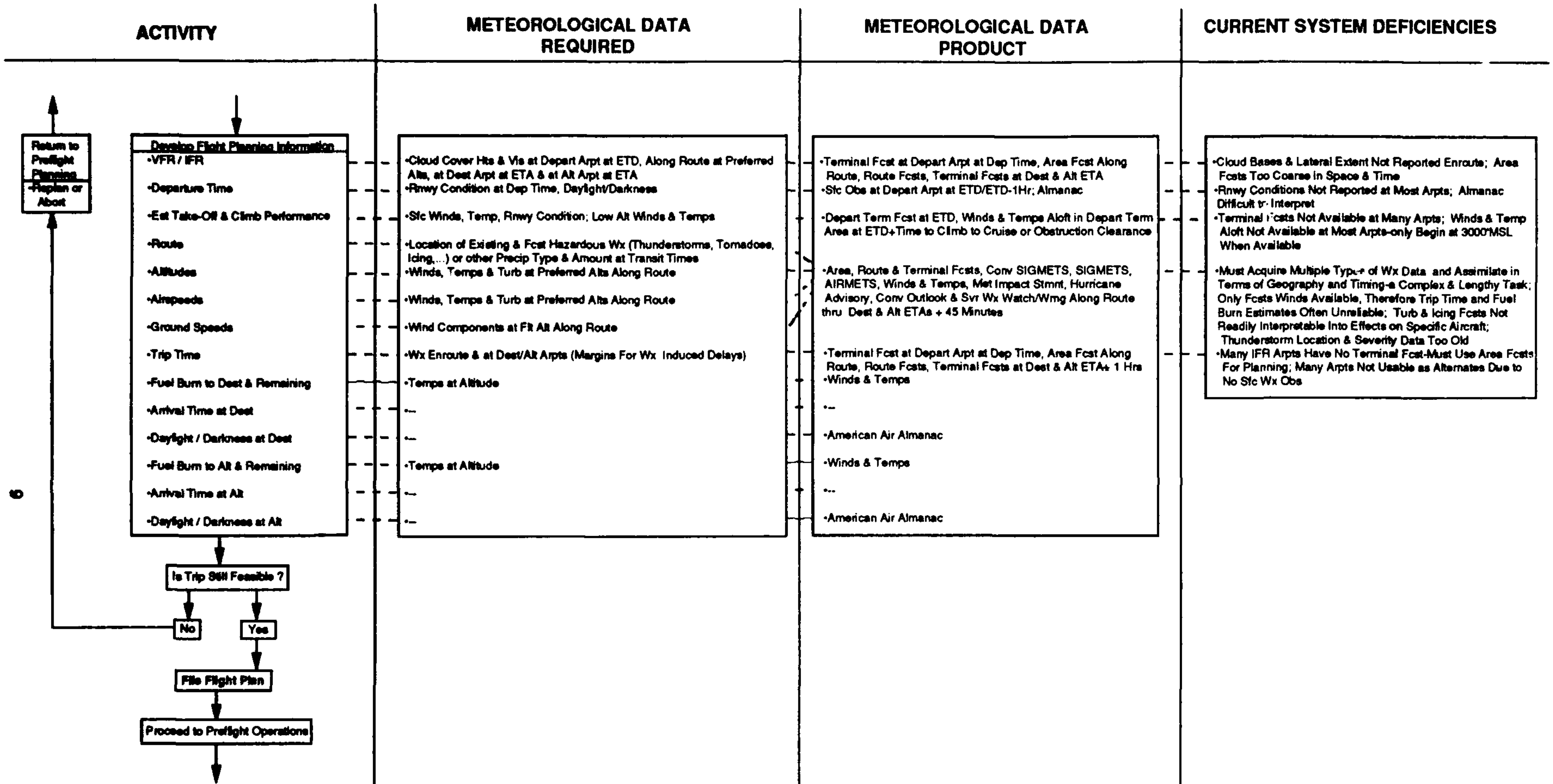

Figure 3. Flight Plan Development

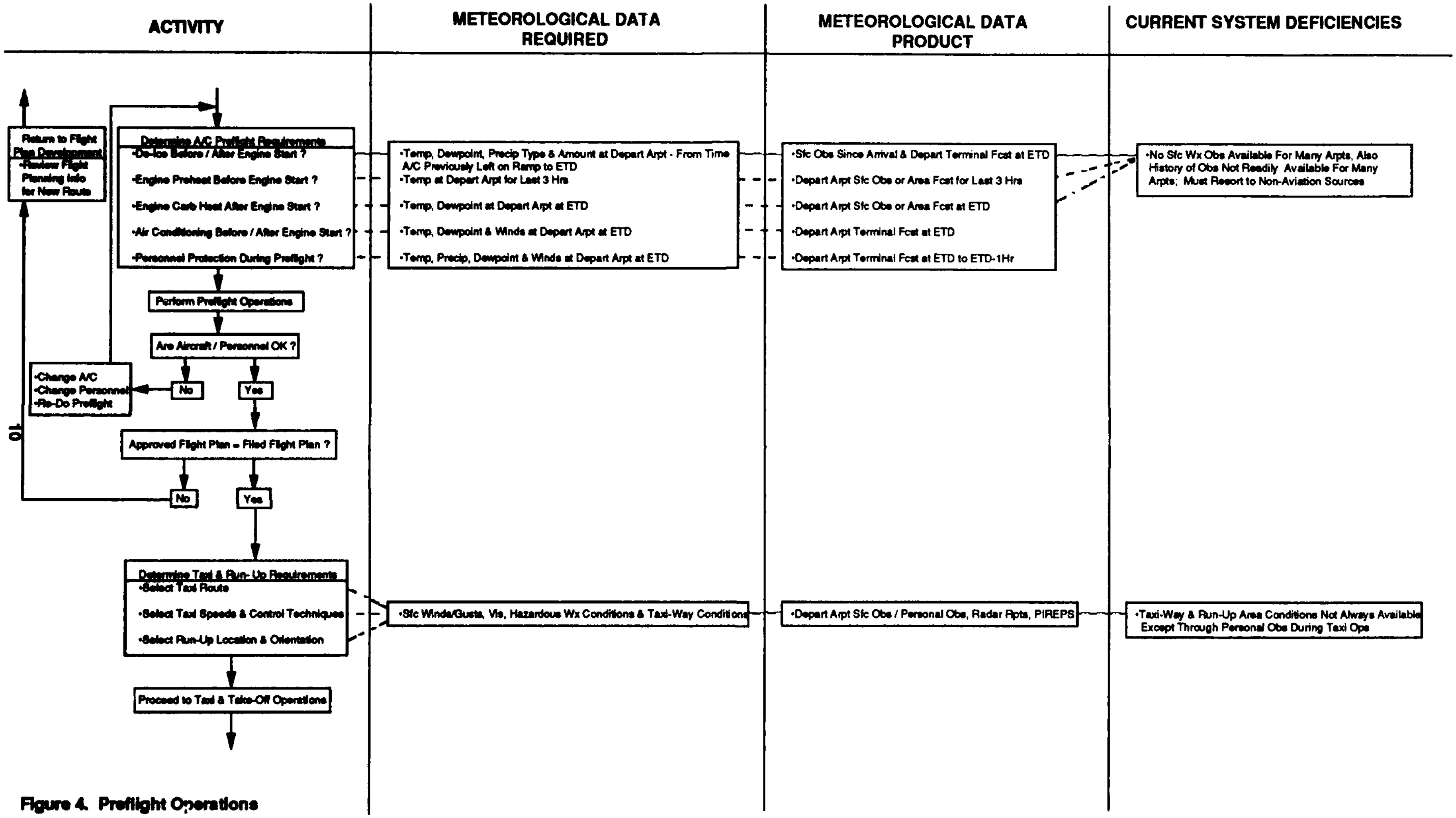

Figure 4. Preflight Operations

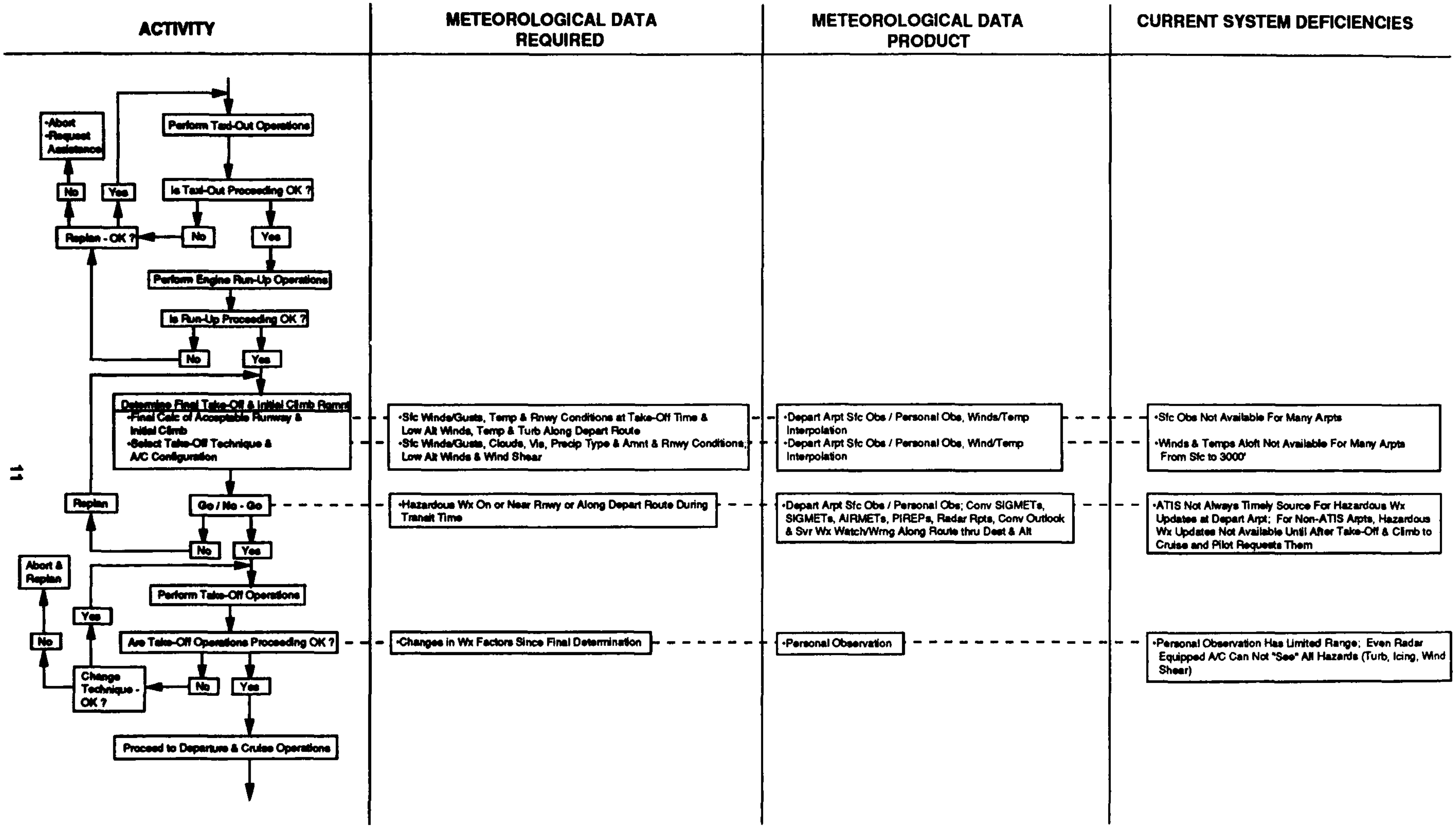

Figure 5. Taxi-Out and Take-Off Operations

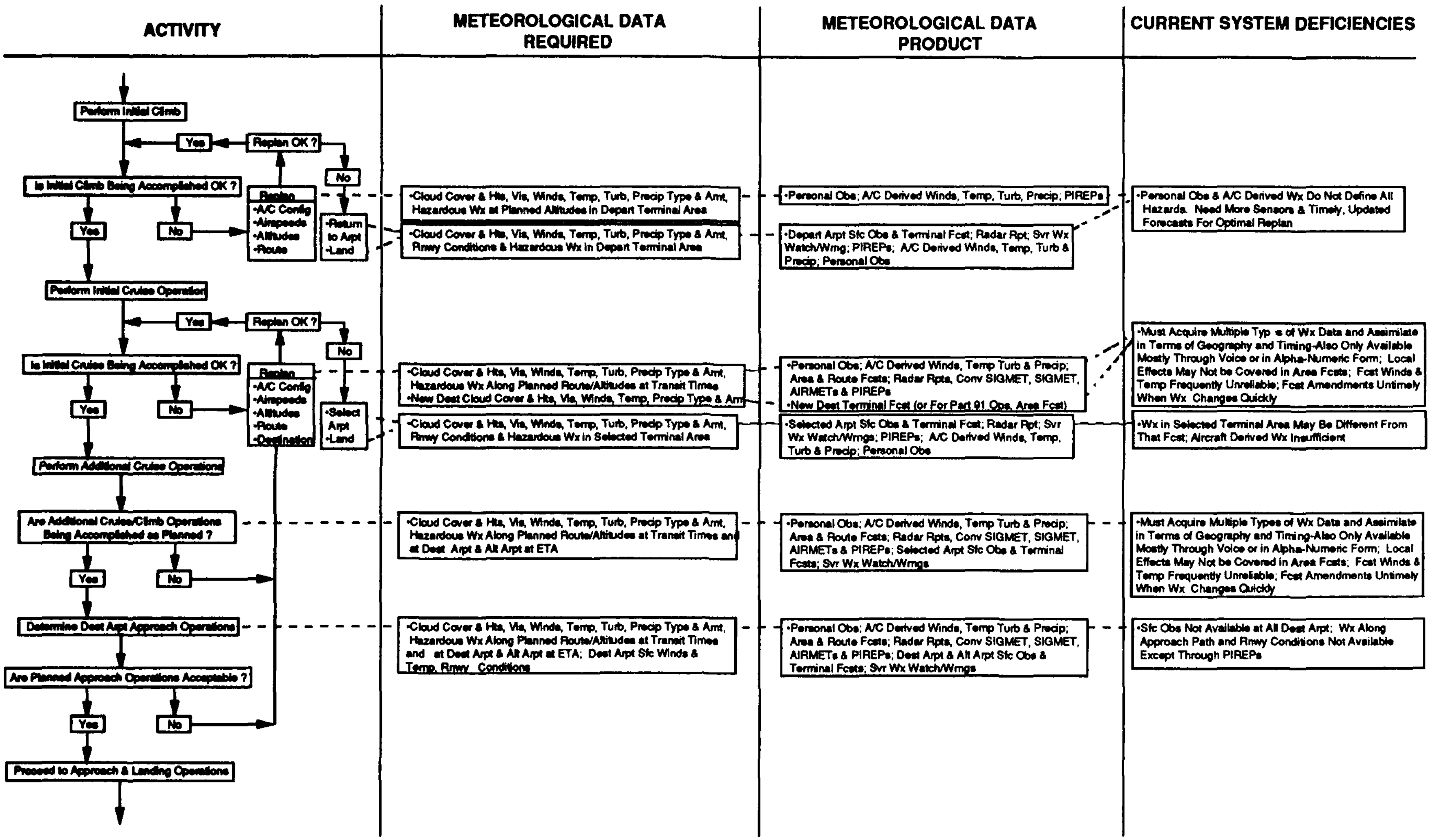

Figure 6. Departure and Cruise Operations

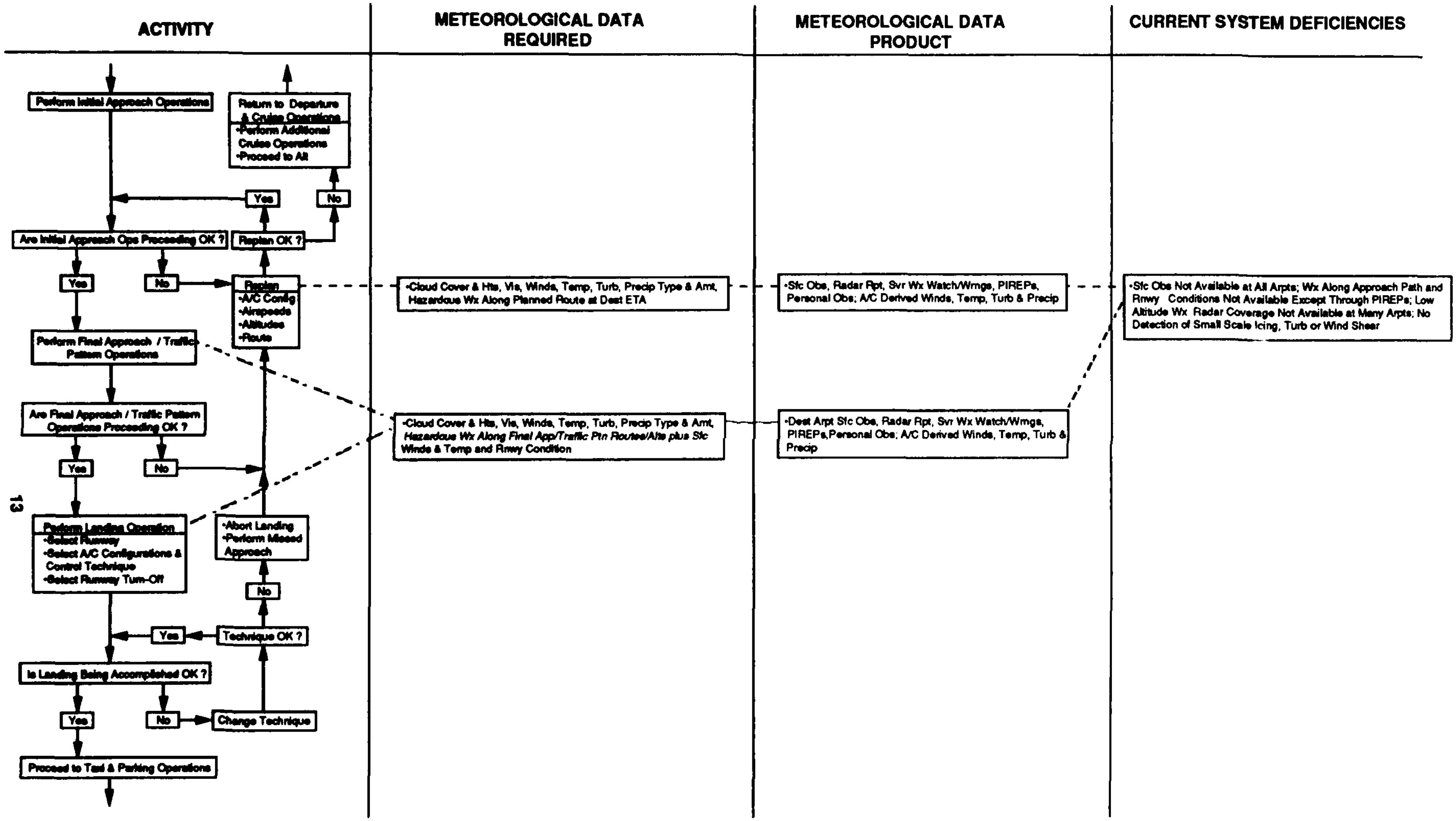

Figure 7. Approach and Landing

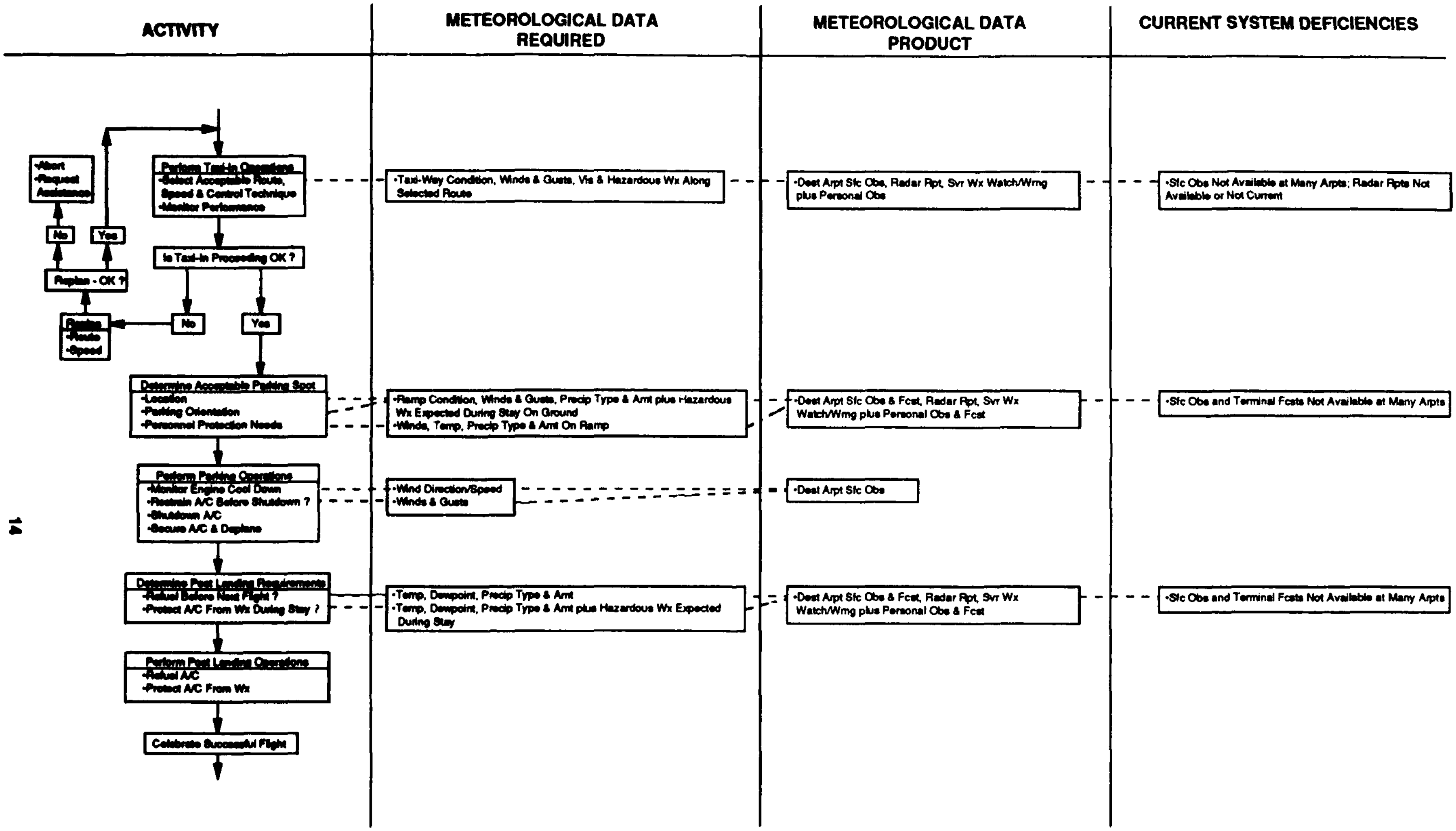

Figure 8. Taxi-In and Parking

ACTIVITY	SURFACE WEATHER INFORMATION REQUIRED	ALOFT WEATHER INFORMATION REQUIRED
Preflight	Summary statement of current and forecast surface conditions along route	Summary statement of current and forecast aloft weather conditions along route
	Time-phased terminal forecasts along route	Time-phased area forecasts along route
	Comparisons of terminal forecasts and surface observations along route for last 3 hours	Comparison of area forecasts and aloft observations along route for last 3 hours
	Location of acceptable alternate airports	
Taxi-Out	Current taxiway and runup area conditions	Significant changes along route since preflight briefing
Take-Off	Current runway surface conditions	Hazardous weather elements aloft in departure terminal area updated since preflight briefing
Departure	Current surface conditions at departure terminal area airports	Hazardous weather elements aloft in departure terminal area updated since take-off
Enroute	Current and forecast surface conditions at suitable accessible airports along route, including destination and alternates	Actual and time-phased forecast aloft conditions along the route with emphasis on location and intensity of hazardous weather to be expected
Descent	Current and forecast surface conditions at destination airport and alternates	Current and forecast aloft conditions in destination terminal area with emphasis on location and intensity of hazardous weather to be expected
Landing	Current runway surface conditions	Current aloft conditions in destination terminal area with emphasis on location, intensity, and movement of hazardous weather
Taxi-In & Parking	Current taxiway and parking area conditions	
Post Flight	Current and forecast surface conditions for stay time	

Figure 9. Weather Information Requirements Scenario Summary