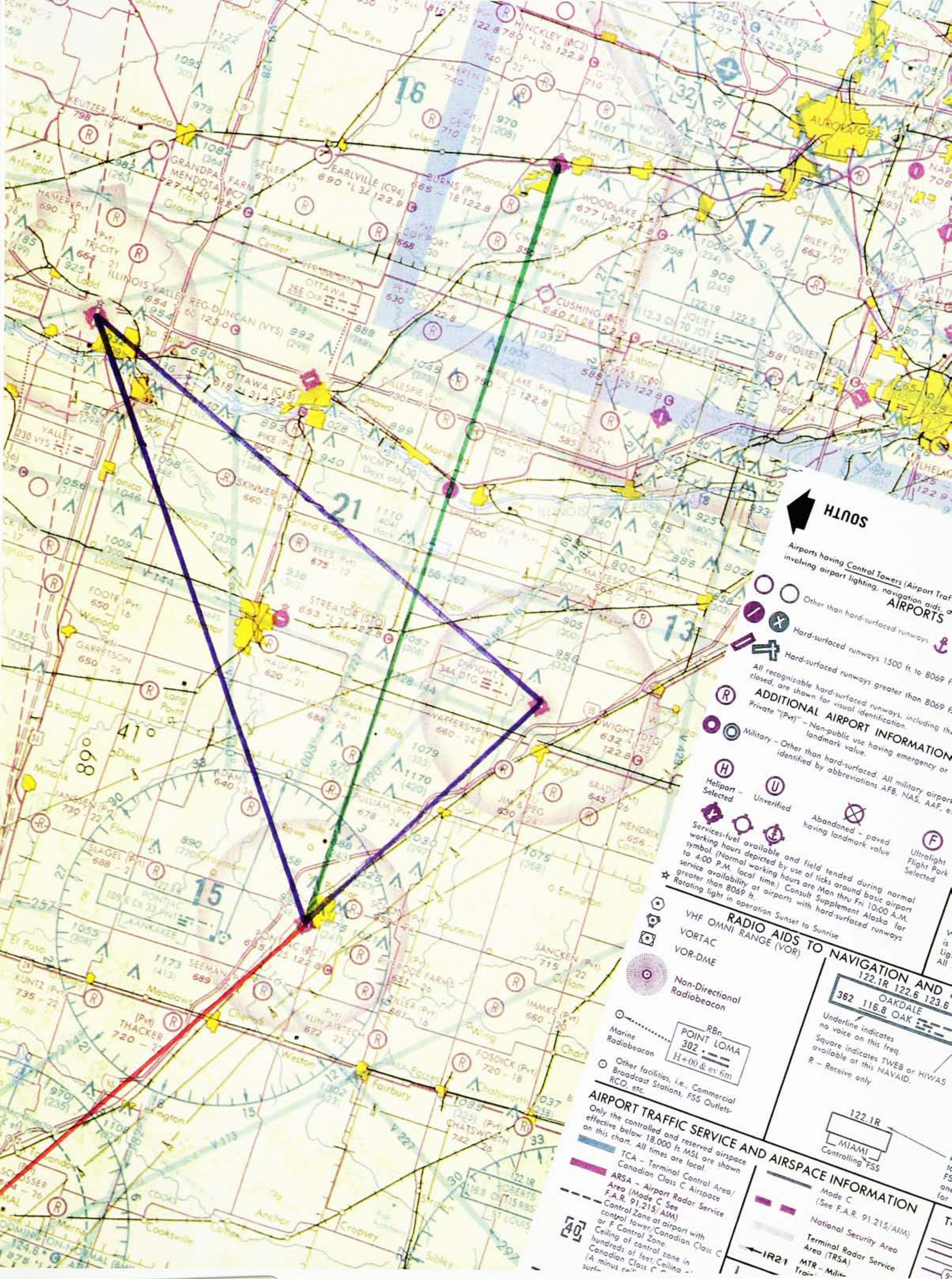
SOUTH
AIRPORTS
Other than hard-surfaced runways
Hard-surfaced runways
All recognizable hard-surfaced runways, including those closed, are shown for visual identification.
ADDITIONAL AIRPORT INFORMATION
Private "(Pvt)" – Non-public use having emergency or landmark value.
Heliport – Selected
Unverified
Abandoned – paved having landmark value
Ultralight Flight Park Selected
Services-fuel available and field tended during normal working hours depicted by use of ticks around basic airport symbol. (Normal working hours are Mon thru Fri 10:00 A.M. to 4:00 P.M. local time.) Consult Supplement Alaska for service availability at airports with hard-surfaced runways greater than 8069 ft.
Rotating light in operation Sunset to Sunrise
RADIO AIDS TO NAVIGATION AND
VHF OMNI RANGE (VOR)
VORTAC
VOR-DME
Non-Directional Radiobeacon
Marine Radiobeacon
RBn
POINT LOMA
302
H+00 & ev 6m
Other facilities, i.e., Commercial Broadcast Stations, FSS Outlets-RCO, etc.
122.1R 122.6 123.6
OAKDALE
362 116.8 OAK
Underline indicates no voice on this freq.
Square indicates TWEB or HIWAS available at this NAVAID.
R – Receive only
122.1R
MIAMI
Controlling FSS
AIRPORT TRAFFIC SERVICE AND AIRSPACE INFORMATION
Only the controlled and reserved airspace effective below 18,000 ft. MSL are shown on this chart. All times are local.
TCA – Terminal Control Area/ Canadian Class C Airspace
ARSA – Airport Radar Service Area (Mode C See F.A.R. 91.215/AIM)
Control Zone at airport with control tower/Canadian Class C or F Control Zone.
Mode C (See F.A.R. 91.215/AIM)
National Security Area
Terminal Radar Service Area (TRSA)
Mendota
Earlville
Sandwich
Aurora
Ottawa
Streator
Dwight
Pontiac
Joliet
Morris
Chatsworth
Fairbury
41°
89°

ROCHESTER INSTITUTE OF TECHNOLOGY

A Thesis Submitted to the Faculty of
the College of Imaging Arts and Sciences
in Candidacy for the Degree of
MASTER OF FINE ARTS

DAEDALUS: Cockpit Flight Management System

By

Jeffrey J. Paris

Date: February 1994

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PREFACE

Federal Air Regulation 91.3 - Responsibility and authority of the pilot in command.

(a.) The pilot in command of an aircraft is directly responsible for, and is the final authority as to, the operation of that aircraft.

(b.) In an in-flight emergency requiring immediate action, the pilot in command may deviate from any rule of this part to the extent required to meet that emergency.

(**Federal Aviation Regulations** - **FAR Part 91 1993, 162-163)**

1.0 INTRODUCTION

The flight and operation of any aircraft in today's busy and complicated airspace system requires training, skill, proficiency, and vigilance. The over-romanticized golden age of aviation barnstorming is long gone. Thankfully one will not hear the old aviation cliche of "kick those tires and light the fires," as daring pilots charged their aircraft into the sky.

The pilot of today, from the commercial airline captain to the recreational general aviation flyer is constantly challenged by cockpit workload. Pilot workload is imposed by a number of outside stimuli, including the particular aircraft being flown (type), air traffic control (ATC), weather, terrain, pilot experience, flight requirements, and by the pilot's own mental and physical abilities.

The purpose of this thesis was to design a portable computer- based flight management system for general aviation pilots. The idea of *Daedalus* arose from the need to ease pilot workload and to help organize the cockpit more efficiently, thus promoting safety and reducing pilot error. The purpose of a cockpit flight management system is to help the general aviation pilot make better decisions and to discourage bad flying habits. In the airline industry this is known as Cockpit Resource Management (CRM).

Daedalus integrates an E6B flight performance calculator, ROM memory, liquid crystal displays (LCD), heads-up display (HUD), electronic pen and notepad (personal data assistant capability), and preprogrammed data cards for each aircraft a pilot may fly. The data cards empower *Daedalus* with a particular aircraft's checklists, standard operating procedures (SOP), and emergency procedures in a convenient format. *Daedalus* is then prompted by the pilot through all phases of aircraft operation from preflight to start up, run up to takeoff,

Fig. 1-1

Enter/Check
Emergency
Shutdown
Landing
Cruise
Notebook
Takeoff
Run-up
Start-up
Shift
Enter/Check
ON
OFF
CONV
CLK
daedalus

climb through cruise, and finally landing and shutdown.

This familiar quotation captures the essence behind the creation of *Daedalus:*

> "Aviation is in itself not inherently dangerous. But to an even greater degree than the sea, it is terribly unforgiving of carelessness, incapacity or neglect." (Trollip and Jensen 1991, x)

Pilots owe it to themselves and the passengers they fly to be as well prepared as possible for every flight they make.

2.0 ACCIDENTS & PILOT ERROR

"Aviate, Navigate and Communicate" is the pilot's litany and one of the cardinal rules of aviation that all students learn from their flight instructors. Moreover;

> "Modern aviation has at its root a three-legged premise: Aviate, Navigate and Communicate. It is the nature of actual flying that these elements are simultaneously experienced and applied to the pilot. To fly is to aviate; to fly to a destination is to navigate; and an essential factor of flying somewhere safely is thorough communication with the air traffic control system." (Sadlowe 1991, 54)

Simply put, don"t get behind in flying the airplane. However, the typical general aviation accident is usually preceded by a chain of events in which the pilot progressively fails to stay ahead of the situation and the aircraft. Accident statistics indicate that "more than 80 percent of the accidents in general aviation today are caused by pilot error, not by major malfunctions of aircraft systems." (Trollip and Jensen 1991, 2) Another study cites, "Human performance issues appear as primary or associated causes in 60-80 percent of aviation accidents and incidents." (Barnes-Svarney 1992, 42)

2.1 Pilot Error

The question that we must ask now is; What is pilot error? Pilot error is defined as:

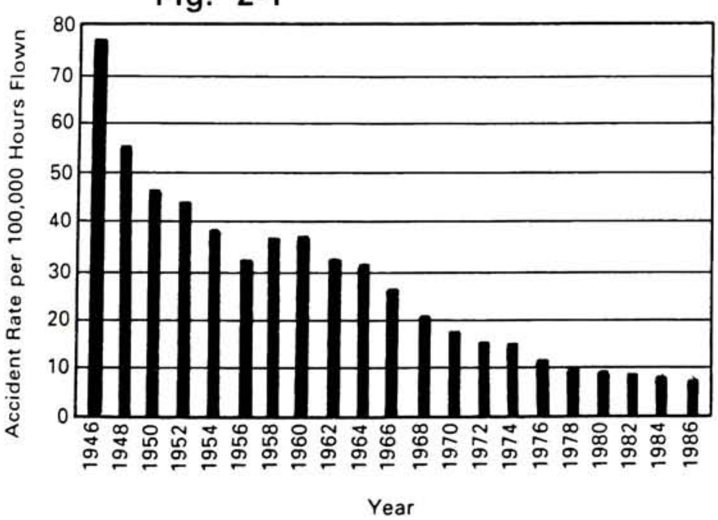
> "An action or decision of the pilot that if not caught or corrected, could contribute to the occurrence of an accident or incident. Inaction or indecision are included in the definition." (Trollip and Jensen 1991, 3)

In addition, it should be noted that the term "pilot error does not imply that all errors are the fault of the pilot. Sometimes external circumstances are the cause, such as poorly designed instruments, controls in the cockpit, or ambiguous regulations or communications." (Trollip and Jensen 1991, 3)

Moreover, even though aeronautical science and technology have made exponential gains in aircraft reliability and safety, one factor remains constant, in that human beings have developmentally remained the same since the beginning of manned flight. (Barnes-Svarney 1992, 43) Aviation accident statistics prove that:

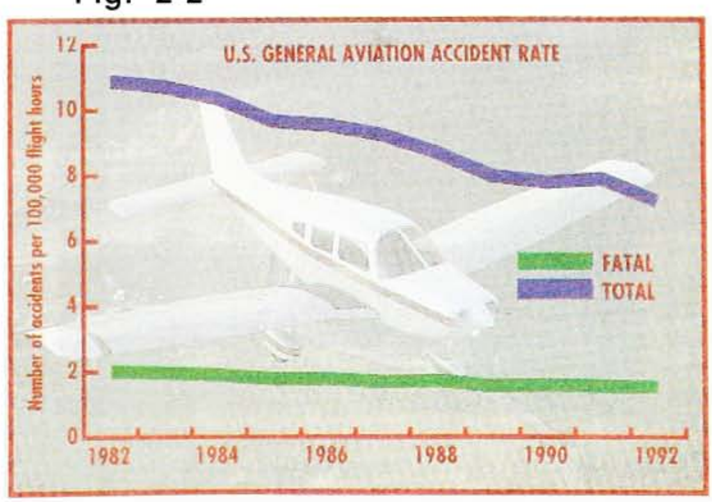
> "General aviation is safe and getting safer; It's safety record has been improving steadily for more than 50 years. The fatal accident rate has steadily declined to less than two per 100,000 flight hours. In 1990, more people were killed on bicycles than were killed in general aviation accidents." (Swanda 1992, 34)

Fig. 2-1



(Trollip and Jensen 1991, 13)

Fig. 2-2



(Landsberg 1993, 121)

However, although accident statistics continue to improve, in 1990 there were 736 fatal general aviation accidents. (Swanda 1992, 34) In addition, according to the National Transportation Safety Board (NTSB) which investigates, researches and compiles accident data finds that:

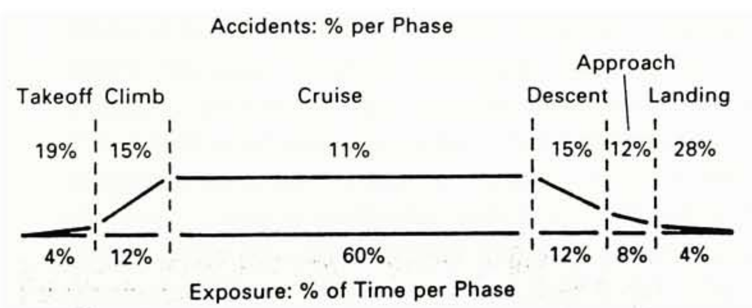
> "In 1985, the pilot was found to be a 'broad cause-factor' in 84% of all accidents, and 90.6% of all fatal accidents. This means that the responsibility for accidents is largely the fault of people, not the machines they fly." (Trollip and Jensen 1991, 13)

More precisely, "The most common, specific causes of the accidents, in order of frequency are:

* **Loss of directional control**
* **Poor judgment**
* **Airspeed not maintained**
* **Poor preflight planning and decision-making**
* **Clearance not maintained**
* **Inadvertent stalls**
* **Poor crosswind handling**
* **Poor inflight planning and decision-making**

As you can see, almost all of these are a result of poor pilot performance, not a result of equipment malfunctions." (Trollip and Jensen 1991, 13)

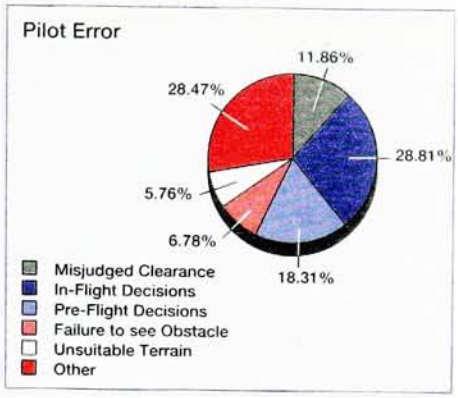
Fig. 2-3 Accident Distribution by Phase of Flight



(Trollip and Jensen 1991, 14)

Figure 2-4 depicts pilot error in a pie graph format.

Fig. 2-4



(Hamilton 1993, 12)

3.0 PILOT WORKLOAD, SITUATIONAL AWARENESS, ERROR CHAINS and DECISION-MAKING

"A superior pilot is one who stays out of trouble by using superior judgment to avoid situations which might require superior skill." (Hamilton, 1993, 12) If pilot performance is the main issue in aviation accidents, then our discussion must focus on the flying individual. It must be said that the best way to prevent flying errors and problems is to recognize them before they start.

> "Since the 1950's very significant inroads have been made into the incidence of technical failures in aircraft. Modern aircraft are highly reliable; However, no correspondingly dramatic improvements have been made in the human components of the system. Within the statistics, there appears to be a hard core of 'human error' accidents that is remarkably persistent. In fact, 80-85% of civil aircraft accidents can be attributed to pilot error (Jensen 1982). And 50% of these are a result of faulty pilot judgment (Jensen and Benel, 1977). Never-the-less, explicit instruction in decision-making has virtually ignored in flight training programs (Jensen, 1982). The traditional view has been that judgment can only be acquired as a by-product of lengthy and varied flying experience. However, recent evidence indicates that pilots do display better judgment after formal decision-making courses (Buch and Diehl, 1984)." (Sadlowe 1991, 25)

Flying can be like juggling too many balls in the air at the same time; pilot workload, situational awareness and decision-making are three worthy areas of study in promoting aviation safety, while reducing accidents and their consequences.

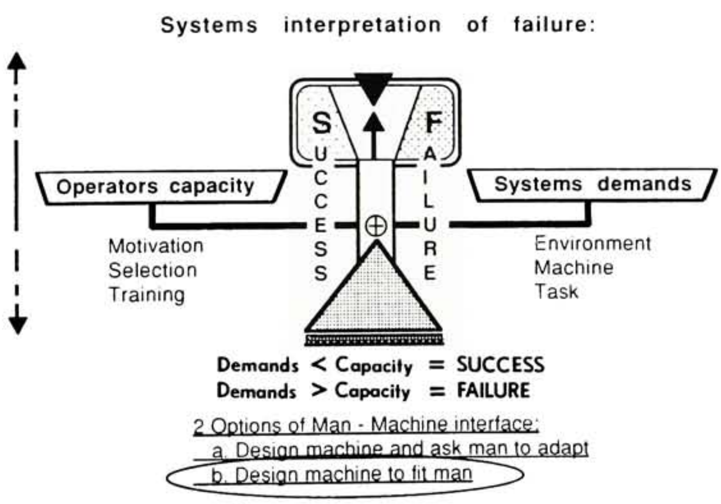
3.1 Pilot Workload

Pilot workload is defined as:

> "The workload imposed by a particular aircraft and flight mission is comprised of perceptual (visual, aural and tactile senses), mental (cognition) and motor (musculoskeletal) activity." (Mohler and others 1981)

Pilot workload is also the product of how the pilot perceives himself and the task at hand, achieved skill level, recent proficiency, general physical fitness and the state of the rest-fatigue cycle, including degree of anxiety (if any), and the presence of illness or chemical dependencies. (Mohler and others 1981) A systems point of view can help define the criteria of human performance as it relates to completing a task successfully. Figure 3-1comes from RIT's own Dr. Jake Shealy, which pictorially models system failures due to operator errors caused by excessive workload. The model is simple, if demands on the operator exceed his workload capacity, the result is system failure. On the contrary, if demands on the operator are less than his workload capacity, the result is system success, and well within the operators capacity.

Fig. 3-1



In summary, subtle changes to a system can have a big effect on operator performance. Therefore, the goal of the system designer is to reduce pilot workload and create an environment in which there is a surplus of operator capacity, thus increasing flying safety while reducing the potential for accident. One must acknowledge that a pilot's flight proficiency and skill is the direct result of his/her mental outlook and physical abilities, as well as training, time in type and recent flight experience. Conversely, loss of proficiency in any learned skill is a predictable result of lack of recent experience.

3.2 Situational Awareness

Along with workload, flight safety is bolstered by a pilot's situational awareness. Situational awareness can be defined as:

> "An accurate perception of the factors and conditions that affect the aircraft and flight crew during a specific period of time. Another way of looking at it is to think of situational awareness as 'having the big picture' or 'being ahead of the airplane'." (Cook and Golbey 1990, 53)

The connection between situational awareness and safety is obvious; the higher a pilot's situational awareness, the lower his/her exposure to risk. For example, all pilots will agree that airspace, navigation and radio (ATC) communications have become more challenging and complex. Pilots of all aircraft have an increasing tendency to look down into the cockpit while trying to organize competing incoming information. However, in an attempt to monitor, collate and manage flight information in a timely fashion, a pilot can be diverted from looking out the window of his craft; which is obviously an unacceptable condition whenever visual flight rules prevail. Thus, when a pilots attention and abilities are continually being called upon with an ever-increasing amount of task (workload), there is a corresponding drop in situational awareness, which can set the stage for error. (Cook and Golbey 1990, 57)

3.3 Error Chain Concept

It is often said, 'that one error often begets others,' and manned flight is no exception to the rule; but rather, accidents are the sum of a number small errors that can eventually pile up and result in serious consequences. What the reader will discover is that accidents are the result of a chain of errors that once set in motion act in a domino effect, which can end in disastrous results if not caught early by the pilot.

> "The error chain concept recognizes that 'human error' accidents are the result of a sequence of events that culminate in a mishap. Seldom is one event alone responsible for an accident or incident. Rather, a number of events, one following another, raise cumulative risk exposure of a flight. If a pilot is adept at recognizing these events as they take place, he can take steps to interrupt any potentially dangerous sequence before it forms an unbreakable chain." (Cook and Golbey 1990, 54)

The prime objective of a pilot or crew members is to avoid building links into the error chain. A loss of situational awareness can result from these nine scenarios:

1) **Ambiguity exists:** When two or more independent sources of information- - - instruments, manuals, pilots or gauges don't agree.

2) **Confusion/Empty feeling:** A sense that every thing is not quite right with a flight

3) **Unresolved discrepancies:** Occurs when there is a failure to settle conflicts of information or opinion. (Can be a very powerful distraction.)

4) **Fixation/Preoccupation:** Often the result of distraction, can lead us to devote our full attention to one item or event to the exclusion of others.

5) **Incomplete communications:** Can result from withheld information, or opinions, or from a failure to resolve misunderstandings or disagreements.

6) **Use of an Undocumented procedure:** When an abnormal or emergency situation exists, do you know where to look in the flight manual or checklist for appropriate guidance?

7) **Violating operating limitations or Minimum operating standards:** Either intentionally or unintentionally involving weather, speed limitations or altitude restrictions.

8) **Failure to meet targets:** Whether those targets are ETA's (Estimated Time of Arrival.), altitudes, speeds, approach minimums, headings or fuel reserves.

9) **Departure from standard operating procedures:** Procedures which were devised to save both pilot and aircraft.

(Cook and Golbey 1990, 56-57)

Recognizing the potential for the error chain concept is an important step in reducing pilot error, while increasing one's situational awareness and flying safety.

3.4 Decision-making

So much of flight training is geared to teach pilots how to handle in-flight emergencies such as engine failures or electrical system malfunctions after the fact. However, little time is spent teaching pilots how to recognize and monitor the existence of potential problems, which in turn could minimize the risks associated with a in-flight malfunction that could lead to an accident. The best way to reduce the risks of flying to acceptable proportions is to teach pilots to make better decisions. Moreover,

"Experience has shown that good judgment is something

> that can be taught. This is significant because human error ranks so high as a principle cause of aviation accidents. Judgment training is designed to make pilots aware of the fact that accidents are the product of an evolving chain of events and to understand that pilots can, to a large extent, exert influence on key events." (Horne 1989, 198)

Furthermore,

> "Pilot decision-making is the process of recognizing and analyzing all available information about oneself, the aircraft, and the flying environment, followed by a rational evaluation of alternatives to implement a timely decision that maximizes safety. Pilot decision-making thus involves one's attitudes toward risk-taking and one's ability to evaluate risks and make decisions based upon one's knowledge, skills, and experience. Pilot decision-making always involves a problem or choice, an unknown element, usually a time constraint, and stress. (Swanda 1992, 31)

However, what constitutes good pilot decision-making? During WWII the Army Air Force stated; "A student showed good judgment when he was able to synthesize all of the aspects of his flying training and produce a safe and efficient result." (Miller 1947, 50) Naively, it seems fair to say that the Army Air Corps criteria of good pilot judgment is a bit cloudy. Pilots often joke that there is no such thing as a bad landing as long as you can walk away from it. Funny? Not really in retrospect of accident statistics and lost lives.

The problem with pilot decision-making is that flying complexity is rapidly approaching the limits of human capability. Interestingly;

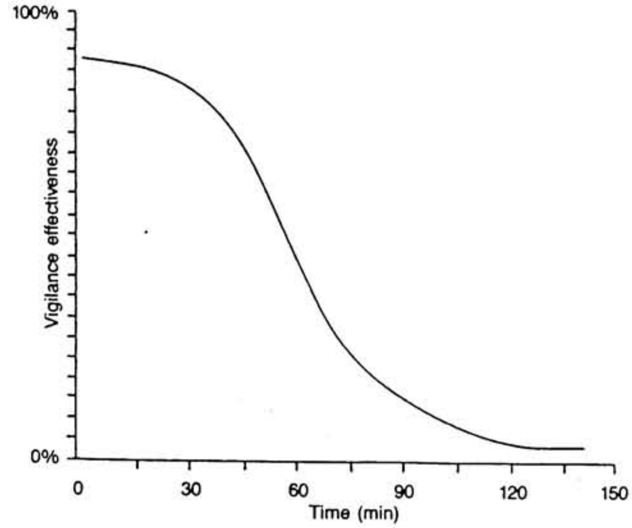
> "One very fundamental characteristic of the information processing system (brain) requires mention. Although man has a vast capacity for sensing information, the decision-making stage of the process consists of just one single channel. In other words, although information may be sensed from the approach lights, altimeter, the airspeed indicator and ATC. The decision-making channel is being time-shared between different inputs this bottleneck impedes the whole

processing system (Broadbent, 1958; Poulton, 1971)."
(Hawkins 1987, 37)

The main deficiency with the human brain is that man's short-term memory is notoriously unreliable; retrieval errors are common in which data is misplaced or forgotten, thus setting the stage for error. For example aircraft checklists can become a boring routine of repetitive tasks that can cause complacency and a loss of motivation in the pilot. (Hawkins 1987, 42) Furthermore, human performance and error rates are directly influenced by the amount of challenge and stimulation of a task; this is known as vigilance effect.

> "It has long been recognized that man's performance of tasks requiring him to monitor or detect brief, low intensity and infrequently occurring events over long periods of time is poor. In 1943, the Royal Air Force (RAF) asked if laboratory tests could be done to determine the optimum watch length for radar operators on anti-submarine patrol, because it was believed targets were being missed. Mackworth later devised a test to simulate the task of a radar operator and this represented the first attempt to explain the phenomenon which has become known as the **vigilance decrement** or **vigilance effect** (Mackworth 1950). The RAF had found in Coastal Command that a marked deterioration in efficiency occurred after about 30 minutes and this has been confirmed many times since. Much of the research on the vigilance decrement has been done in laboratory studies.
> These have not always been representative of the operational environment, where many factors, not least, motivation, play a role, so that many such studies may have little operational application (Smith *et al.*, 1969). However, there have also been many industrial studies, particularly in Japan, and these have generally revealed such a decrement, although subject to individual difference (O'Hanlon *et al.*, 1977). Practice does not seem to be effective in eliminating the decrement."
>
> (Hawkins 1987, 42)

Fig. 3-2



An illustration of the kind of vigilance effect which can be expected in the performance of passive tasks with low signal rate. This shows a notable decline in performance after about 30 minutes.

(Hawkins 1987, 41)

The decision-making process occurs directly in response to a stimulus, and requires a person to process the information to draw a conclusion. However, vigilance effect adds to the problem of human performance, because passive tasks like checklist procedures erode over time along with efficiency and safety.

4.0 HAZARDOUS THOUGHT PATTERNS

Ultimately, if a machine or system fails in flight it is a human being that invariably compensates for the malfunction. Furthermore, the pilot will play the role of the ultimate back-up to the machine. The resulting success or failure of the pilot to meet the situation relies on his/her understanding of the problem and his/her ability to think rationally. Moreover, it is a pilot's mental attitude and make-up that will determine the outcome of an event. (Gerber 1992)

Accidents occur because people are vulnerable to hazardous thought patterns;

> "Hazardous thought patterns are the result of unsafe attitudes toward risk-taking. If a pilot is trained to recognize and apply

an antidote to the hazardous thought patterns that distort the decision-making process, the pilot will make better decisions. The key to safety, therefore is the pilot, who can recognize and apply the antidote to hazardous thought patterns."

(Swanda 1992, 34)

What are the Hazardous thought patterns and their antidotes, See Fig. 4-1.

Fig. 4-1 **THE FIVE ANTIDOTES TO HAZARDOUS ATTITUDES**

Hazardous Attitude	Antidote
Anti-Authority: Don't tell me. The regulations are for someone else.	Follow the rules. They are usually right.
Impulsivity: I must act now, there's no time. Do something quickly.	Not so fast. Think First.
Invulnerability: It won't happen to me.	It could happen to me.
Macho: I'll show you. I can do it.	Taking chances is foolish.
Resignation: What's the use?	I'm not helpless. I can make a difference.

(Swanda 1992, 34) (Jensen and Trollip 1991, 8-20)

Hazardous thought patterns are the nemesis of good decision-making. Again,it is up to the pilot to take an honest look at himself and exorcise the hazardous thought patterns out of his mind; the antidotes more than speak for themselves.

Therefore, we must recognize, minimize and attack errors before they start, while ultimately understanding that pilots have many tasks to fulfill and that errors caught early rarely result in accidents. Pilots must evaluate themselves honestly and understand that it is sheer stupidity to ignore one's weaknesses, and we must realize as human beings we are bound to make mistakes. And finally:

> "The illusion that it is possible to achieve error-free operation has been a convenient concept in simplifying accident investigations, and allocation of blame has tended to discourage proper attention to the second prong of the attack, living with errors, but reducing their consequences." (Hawkins 1987, 43)

5.0 HUMAN FACTORS & COCKPIT RESOURCE MANAGEMENT

"Living with errors, but reducing the consequences," is the goal of human factors research. Since WWII, the military and commercial air carriers have spent millions of dollars on studying the dynamics and misgivings among professional flight crews, with the goal of reducing pilot error and flight accidents. Cockpit Resource Management is a direct outgrowth of human factors research and study. The following excerpt from an International Civil Aviation Organization (ICAO) publication captures the essence of human factors:

> "Human factors is about people. It is about people in their working environments, and it is about their relationship with equipment procedures and the environment. Just as importantly, it is their relationships with other people. Human factors involves the overall performance of human beings within the aviation system; it seeks to optimize people's performance through the systematic application of the human sciences, often integrated within the framework of system engineering. Its twin objectives can be see as safety and efficiency." (Trollip and Jensen 1991, 1)

The focus of human factors research and Cockpit Resource Management training is for all of us to recognize that inadequate aircraft system design or operator training can contribute to pilot error and accidents. Furthermore, we must recognize that inadequate design and management of pilot tasks can contribute to errors that lead to an erosion of system performance.

5.1 Cockpit Resource Management -CRM

The basic Cockpit Resource Management concept is defined as:

> "Cockpit Resource Management (CRM) refers to the effective use of all resources to achieve safe and efficient flight operations and is the extension of pilot judgment to the multi-person flight crew. The primary focus of CRM is on communication, both among those who are inside the cockpit and those who are outside, such as Air Traffic Control (ATC). Communication is the critical factor in cockpit management because it is the means by which management is carried out." (Trollip and Jensen 1991, 9-2)

The primary goal of CRM training is accurate aeronautical decision-making through effective flight crew communication. CRM trains pilots to anticipate events as opposed to reacting to a mishap after the fact. CRM is a training concept concerned with how well a pilot and crewmember work together as a team. The CRM concept recognizes that crew responsibilities, coordination and teamwork on the flight deck are to used as deterrents to human error. CRM fosters a climate in which:

* **Individual tasks are well-defined and standardized.**
* **All cockpit talent is involved in all critical phases of flight.**
* **The monitoring responsibility is expressed in active participation in the information gathering and interpretation process.**
* **The pilot-in-command maintains an atmosphere of creative discontent, that is, every crewmember should feel free to air his/her misgivings about the safety of the flight in an appropriate manner.**

(Bruggink 1976)

Moreover, CRM establishes a clearly understood set of ground rules and procedures for sharing flight responsibilities. For example, here is a more detailed excerpt of a U.S. Department of Transportation/Federal Aviation Administration

Advisory Circular AC120-51A on CRM training:

"b. Crew Resource Management (CRM). The application of team management concepts in the flightdeck environment was initially known as Cockpit Resource Management. As CRM programs evolved to include cabin crews, maintenance personal and others, the phrase Crew Resource Management has been adopted.

(1) CRM now refers to the effective use of all available resources; human resources,hardware, and information. A current definition includes all other groups routinely working with the cockpit crew who are involved in decisions required to operate a flight safely. These groups include but are not limited to:

(i) dispatchers
(ii) cabin crewmembers
(iii) maintenance personal
(iv) air traffic controllers

(2) CRM is one way of addressing the challenge of optimizing the human/machine interface and accompanying interpersonal activities. These activities include team building and maintenance, information transfer, problem solving, decision-making, maintaining situational awareness, and dealing with automated systems. CRM training is comprised of three components: initial indoctrination/awareness, recurrent practice and feedback, and continual reinforcement. Each component must be continually renewed.

7. THE MISSION OF CRM TRAINING. CRM training has been conceived to prevent aviation accidents by improving crew performance through better crew coordination.

8. BASIC CONCEPTS OF CRM. CRM training is based on a awareness that a high degree of technical proficiency is essential for safe and efficient operations. Demonstrated mastery of CRM concepts cannot overcome a lack of proficiency. Similarly, high technical proficiency cannot guarantee safe operations in the absence of effective crew coordination.

a. Experience has shown that lasting behavior changes in any environment cannot be achieved in a short time period, even if the training is very well designed. Trainees need awareness, practice and feedback, and continuing reinforcement: in a word, time to learn attitudes that will endure. In order to be effective, CRM concepts must be permanently integrated into all aspects of training and operations.

b. While there are various useful methods in use in CRM training today, certain essentials are universal:

(1) CRM training should focus on the functioning of crewmembers as teams, not as a collection of technically competent individuals.

(2) CRM training should instruct crewmembers how to behave in ways that foster crew effectiveness.

(3) CRM training should provide opportunities for crewmembers to practice the skills necessary to be effective team leaders and team members.

(4) CRM training exercises should include all crewmembers functioning in the same roles (e.g., captain, first officer, and/or flight engineer) they normally perform in flight.

(5) CRM training should include effective team behaviors during normal, routine operations.

c. Good training for routine operations can have a strong positive effect on how well individuals function during times of high workload or high stress. During emergency situations, it is highly unlikely (and probably undesirable) that any crewmember would take the time to reflect upon his/her CRM training in order to choose the appropriate behavior. But practice of desirable behaviors during times of low stress increases the likelihood that emergencies will be handled effectively.

d. CRM is defined by the following characteristics:

(1) CRM is a comprehensive system of applying human factors concepts to improve crew performance.

(2) CRM embraces all operational personnel.

(3) CRM can be blended into all forms of aircrew training.

(4) CRM concentrates on crewmembers' attitudes and behaviors and their impact on safety.

(5) CRM uses the crew as a unit of training.

(6) CRM is training that requires the active participation of all crewmembers. It provides an opportunity for individuals and crews to examine their own behavior and to make decisions on how to improve cockpit teamwork."

As you can see CRM is a continuous process where training in constantly being analyzed, redesigned, developed, presented, evaluated and revised to enhance crew safety. Again, the important emphasis in not only on the flight crew, but has shifted to encompass the whole aviation system.

5.2 CRM and the Single Pilot

Although, CRM is regarded as an outgrowth of multiperson crew flight training that is geared to professional pilots, CRM is an excellent tool which can be used in a single pilot situation. CRM training and awareness can be helpful to improve cockpit management and safety for any pilot. Furthermore, a large number of general aviation pilots are not alone when flying; in reality they are probably flying with a family member, friend, another pilot, or flight instructor. Basic CRM principles can be used to establish teamwork and communication between a pilot and his right seat passenger.

CRM has set the stage for studies that have made surprising conclusions concerning the attitude traits of an effective pilot-in-command, which is important in evaluating one's personal attitudes toward flying and operating an aircraft. The effective pilot-in-command is one who:

* **Recognizes personal limitations.**
* **Recognizes his/her diminished decision-making abilities in an emergency.**
* **Encourages other crewmembers to question decisions or actions.**
* **Is sensitive to personal problems of other crewmembers that might affect operations.**
* **Feels obligated to discuss personal limitations.**
* **Recognizes the captains role in training other crewmembers.**
* **Recognizes the need for the pilot who is flying the airplane to verbalize plans.**
* **Recognizes the need for a relaxed and harmonious flight deck.**
* **Recognizes that the optimal management style varies as a function of the situation and fellow crew members.**
* **Stresses the captain's responsibility for coordinating cabin crew responsibilities.**

On the contrary, the ineffective pilot-in-command is one who:

- **Is the stereotype of the "macho pilot" with "the right stuff."**
- **Does not recognize personal limitations due to stress or emergencies.**
- **Does not utilize the resources of fellow crewmembers.**
- **Is less sensitive to problems and reactions of others.**

- **Tends to employ a consistent, authoritarian style of management.**

- **Has a flight deck that is more tense than that of a good pilot-in-command.**

- **Has a flight deck reflecting far less team coordination than that of the good pilot-in-command.** (Trollip and Jensen 1991, 9-19-20)

In summary, for single pilot CRM to be successful these four objectives must be reiterated:

> "First, rules and regulations are to be followed without exception. Second, the crew concept gives each member a well defined operational duty. Third, there is to be a high level of safety awareness. Fourth, experience from an operational incident or accident is to be constructively utilized." (DeLacerda 1992, 26)

CRM asks the flight crew as well as the single pilot to constantly evaluate the balance between individual capability and flight workload, while making proper adjustments to keep the flight safe. Pilots must actively use good communication, decision-making and organizational skills, taught by CRM training, and make them applicable to general aviation.

6.0 CHECKLISTS

For many pilots a checkride or biennial flight review by a competent flight examiner or instructor is a time for anxiety and stress. Biennial flight reviews are a way to make sure pilots maintain a level of currency and flight proficiency, while boning-up on the Federal Air Regulations. Flying skills can erode easily over time, especially when a pilot fails to fly regularly. Failure to fly regularly opens the door for bad habits and loss of flight proficiency, which can lead to pilot error. In Webster's Dictionary, proficiency is defined as "The state of art of being proficient, performing in a given art, skill or branch, or learning with expert correctness; adept,

Fig. 5-1

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Under The Hood

by Steve Rollman

skillful." The question we must ask now is, What can every pilot do to help keep themselves proficient and on top of the airplane? Simply, pilots can do four things to keep themselves proficient and flying smarter:

1) Buy a copy of the Aircraft's Owner's Manual. Study the airplane's flight characteristics and and maneuvers, take-off and landing procedures, stall characteristics, important airspeeds, emergency procedures, operating limitations, weight and balance, etc.

2) Take a look at your logbook. Are you current? When was he last time you flew? Flew with an instructor? With passengers? Did a cross country flight? Are you prepared to fly to the letter of the law?

3) How good is your preflight planning? Did you check weather? Did you do a weight and balance calculation? Have you set **<u>your own</u>** flight minimums for winds and visibility? Do you have an alternative flight plan, in case you have to divert enroute or at your destination?

4) **DID YOU USE A CHECKLIST?**

Of the four suggestions above, the most important thing a pilot can do to keep proficient and flight safe is to us a good checklist! (Strock 1981)

Simply stated, "Checklists help a pilot approach an aircraft and its systems in a ordered, systematic and safe manner." (Garrison 1989, 67) Moreover;

> "Checklists are guides for use is ensuring that all necessary items are checked in a logical sequence. The beginning pilot should not get the idea that the list is merely a crutch for poor memory. Even the most experienced professional pilots never attempt to fly without an appropriate checklist. The habit of using a written checklist for the airplane being used should be so instilled in pilots that they will follow this practice throughout their flying activities." (<u>Flight Training Handbook</u> 1980, 48)

In addition and more succinctly;

> "The National Transportation Safety Board (NTSB) accident reports for the last five years include 28 accidents in which misuse of checklists was cited as a cause; fully half involved forgetting to put down the landing gear or to retract the wheels on amphibious floats . . . The next most common problem was

> fuel mismanagement- another checklist related item."
> (Garrison 1989, 72)

The use of a well planned checklist that is easily accessable, mountable, visible and readable to a pilot is a valuable resource. Moreover, the cockpit checklist is major part of cockpit protocol for all military and commercial air carrier crews;

> "Under the aegis of 'Cockpit Resource Management' - A rational approach to dividing the work of flying among two or three people. Checklists are handled by 'challenge and response'; one crewmember calls out a checklist item, and the other performs it or verifies that it has been performed. The checklist in effect becomes a 'Do List'."
> (Garrison 1989, 74)

The goal of CRM training and the use cockpit checklists is to enforce a systematic approach to cockpit procedure, which raises a crews situational awareness and level of safety.

Another advantage of using a checklist is that it allows the pilot to mentally prepare for a procedure in his/her head before the task is to be done; thus giving the pilot ample time to perform the task, while simultaneously raising his/her expectation level for the correct procedural response. For example, in situations where a pilot may be under stress due to a time constraint, it is easy to let checklist procedures slip from memory. With the use of a checklist the pilot can consciously avoid skipping procedures that may result in a situation that leads to pilot error and accident.

> "When you ignore a good procedure because of pressures of time, you can find yourself in double jeopardy - The procedure is not done at a time when it is most needed, and, if something goes wrong, you may be too stressed to handle the ensuing emergency." (Trollip and Jensen 1991, 2-9)

Finally there are four important reasons for using checklists. First, the use of a thorough and well designed checklist is a must for any conscientious and serious pilot. Secondly, aircraft manufacturers wholeheartedly want to see that pilots operate their products in a safe and efficient manner. Third, accident statistics and pilot fatalities are no joke and are a terrible reality . Fourth, why not? What do you have to lose? Only your life!

6.1 Checklist Drawbacks

The one problem with most checklists used by today's general aviation pilots is that pilots get so accustomed and comfortable with the checklist and aircraft they fly that they easily miss items on the list, or fail to use it at all; which can lead to three types of error:

> "One of the most common errors recognized is failing to do something which ought to be done such as missing an item on a checklist. This is called an error of **omission** and introduces another way errors can be classified. An error of **commission** is doing something which ought not to be done. A third kind of error in this form of grouping is the error of **substitution**, which is taking action when it is required, but the wrong action. This kind of error has lead to disaster on a number of occasions when the pilot closed down the wrong engine after an inflight failure." (Hawkins 1987, 39)

Errors of omission are obvious, like missing an item on a checklist; however, much more insidious are errors of commission and substitution. Errors of commission and substitution are the result of negative training transfer. Negative training transfer can be defined "as an error that is associated with earlier training or practice that is difficult to unlearn, particularly under stress conditions." (Hawkins 1987, 181)

The problem with negative training transfer is that previous learned tasks interfere with the learning of new tasks. Moreover, the pilot who uses the same checklist for the same aircraft over and over tends to develop 'set expectations' and, as a result, they become oft-repeated habits.

> "Flight and simulator training and the learning of standard operating procedures (SOPs) are aimed a establishing a pattern of habitual behavior. Because of this practice of standardizing equipment and procedures within a aircraft, it is also often possible for the operating habits formed on one aircraft to be carried over to subsequent aircraft."
> (Hawkins 1987, 34)

For example, it has been said by some very simplistic flight instructors that transitioning from piloting a Cessna 150 to piloting a Cessna 172 is just a simple matter of "adding five knots to all the operating airspeeds", which is a gross misrepresentation of the complexities between these two aircraft. Furthermore;

> "Experience and habit, however, may not always be beneficial. Once a certain pattern of behavior has been established, it may be difficult to abandon or unlearn it, even when it is no longer appropriate . . . Aircraft are believed to have crashed from this type of human error, resulting for a reversion to an earlier behavior pattern. (Rolfe, 1972)" (Hawkins 1987, 34)

Moreover;

> "A characteristic of reversion is that the original experience or habit concerned may not have revealed itself for a very long time and the person concerned may be quite unaware of the danger lurking just beneath the surface." (Hawkins 1987, 34)

And finally, the last problem with standard checklists is human motivation:

> "Motivation reflects the difference between what a person can do and what he will do in any particular set of circumstances. A fundamental weakness in traditional forms of proficiency checking and testing is that they generally only show a person's capability or capacity under test conditions. They do not necessarily reflect his performance or reliability when away from the test situation and supervision. If the motivation to perform a particular task is too low, then a reduced performance with more errors can be expected. (Hawkins 1987, 34)

A case in point: many pilots use a checklist thoroughly only when they are having a flight review or working with an instructor. However, experience and the religious use of an aircraft's checklist does lead to a reduction in errors and accidents. Regardless of errors of omission, commission and substitution, the use of a checklist will make a pilot less vulnerable to error and will lower his/her exposure to risk.

7.0 ELECTRONIC COCKPITS AND COMPUTERS

Aviation electronics and avionics has been one of the necessary pillars upon which technological progress has been built.

> "The advanced electronic displays and controls in modern aircraft reflect over a century of development. The evolution has taken place not in order to make the flight deck more comfortable or convenient as a workplace, but as a result of two major pressures; safety and economics; between which there is an inescapable interaction." (Hawkins 1987, 224)

The military and commercial aircraft transports of today are increasingly dependent on information supplied by "glass cockpits". Glass cockpits are simply electronic flight instruments that share a vast wealth of information with their flight crews via cathode ray tubes (CRT). The glass cockpit of today is known as Electronic Flight Information System or (EFIS), whose purpose is to help pilots and flight crews optimize their decision-making abilities. Avionics architecture has moved from the analog age into the digital age, in which aircraft operating checklists and software are hardwired right into the aircraft and available at the touch of a pilots fingertip. As one writer states;

> "Electronic devices will not be denied, however; airlines are now looking at electronic checklist readers, which are already in use in business jets. Preprogrammed with a checklist, the device reads an item (with a synthesized voice) and the crew-

member can press a button (or, conceivably, could even respond verbally) when an item has been checked. Such a system has the advantage over human operators in that it can't forget where it is in the checklist; If it doesn' t get a response within a certain period of time it starts to complain."
(Garrison 1989, 74)

In addition, general aviation is also benefiting from the technological advances in avionics and electronics that trickle down. As of today, general aviation pilots can purchase and utilize Loran (Long range navigation receivers), GPS (Global Positioning Satellite Navigation Receivers), moving map displays, Stormscope thunderstorm avoidance Weather Mapping Systems as well as TCAS (Traffic Collision Avoidance System radar). Moreover, with the growing use of personal computers in the home, dedicated aviation software is becoming available for use in getting pilot weather briefs (DUAT) and filing flight plans with the FAA . For instance;

> "In the early 1980's, improvements in processing power, graphic capabilities, and mass marketability of personal computers gave rise to software that depicted flight. These early flight simulators were extremely successful and were marketed by software vendors as entertainment. However, due to the success of these early products and coupled with additional advancements in microprocessor technology, the mid-to-late 1980's brought serious efforts to develop PC-based simulators devoted to instrument flight. Due to the high cost of conventional simulators these new products were a success within the general aviation community. One advantage personal computers have is the combination of the flight instruments and visual system lie within the computer monitor or CRT display. However, obstacles existed: (1) user interface (e.g. keyboards) did not replicate an airplane cockpit, and (2) the FAA was slow to recognize, acknowledge, and approve their use for pilot training and currency requirements." (Sadlowe 1991, vii)

Furthermore;

> "The recent development of personal computers that are within the budget of general aviation, suggests if properly used, PC's

> could be utilized to provide some of the training. There is some empirical evidence to suggest and support the training effectiveness of microcomputer-based technology in task simulation contexts. This was demonstrated by Poleman and Edwards (1983) who showed that a computer-aided, two-dimensional graphics simulation can be superior to material presented in illustrated textual manner in the transfer of cockpit procedural skills." (Sadlowe 1991, 14)

Finally, the development of laptop computers and their flat panel displays are redefining the way people work. Laptop computers offer consumers mobility, software utility, high power and compact convenience anywhere a person wants.

Interestingly, it is not surprising in some instances to see laptop computers being used for general aviation applications, such as software linked in conjunction with a GPS or Loran receiver to create a real-time moving map displays for pilot navigation. However, laptops are not specifically designed with general aviation aircraft use in mind, especially since laptops are not the easiest to mount or use while trying to input commands at a 120 knots.

8.0 PDA's (Personal Digital Assistants)

One of the most exciting and promising developments in personal computing in the 1990's is with the introduction of PDA's or (Personal Digital Assistants). As Bill Evans of ID Magazine writes in his article entitled "Pen Computing: Beyond the Mouse and Laptop.", PDA's simply are "Electronic ink manipulating smart paper." (Evans 1992, 89) Another author writes that PDA's, "Wraps advanced hardware and sophisticated software in a portable package that presumably anyone can use and appreciate." (Soviero 1992) Furthermore;

> "Unlike full-blown computers, the PDA's are designed as tightly focused, limited-purpose machines. For example, the first shipping model will be primarily for quick note

> taking; schematic sketching; simple letter writing; and performing basic personal-information management functions such as an address keeping book, calender, and scheduling databases." (Ito 1992, 45)

Already, companies are marketing and selling their versions of PDA's; Apple Computer is introducing *Newton* (See Figure 8-1), AT&T has its *Personal Communicator,* Go has *Pen Point*, NCR has *System Notepad,* Sharp has a pen-based *OZ-9600* and *PV-F1,* and Sony has *PTC-300 PalmTop.*

The interesting fact about PDA's is that they don't us a keyboard or mouse to operate. On the contrary PDA's use a pen-based stylus and touchscreen technology to make data inputs. Unlike conventional PC computing;

> "Pen-based computers . . . are powerful tablet-like devices that operate more like notebooks than computers. As their name implies, you control such computers with a special pen that the screen senses. You write directly onto the screen, and the computer translates the handwriting into ASCII text." (Carr 1991, 211)

In addition,

> "The computer also holds the input stylus, a cordless device that looks like an engineering pen or pencil. The stylus interacts with an electromagnetic field that passes across the surface of the screen. Thus, the system can tell where-the stylus is and whether it is touching the screen."
> (Lindeholm 1991, 218)

The most impressive feature about PDA's is their ease of use, especially because far more people know how to use a pencil than know how to type. (Linderholm 1991, 218) So, what are the other advantages of a pen-based notepad computer? The answer is simple: the PDA has the ability to recognize and learn the unique intricacies of the users penmanship with each use and translate it into ASCII text. For example, Go's *Pen Point* uses a a handwriting

Fig. 8-1

TON: THE INFORMATION TASKMASTER

Newton's intelligent software makes the device more akin to an assistant than an electronic organizer or a personal computer. Newton learns key phrases such as "fax this," or "remind me of that," and makes simple assumptions to assist you with such tasks. For example, say you jot down a letter to Larry, followed by the phrase "format this." Newton will select a business form letter from memory and automatically format the letter with Larry's address pulled from your electronic address book. Now you want to fax the letter? Hook Newton up to a fax machine write "fax this to Larry" on the screen, and the device will automatically churn out a fax cover letter, fill in the appropriate cover information, pull up Larry's fax number, and send the fax.

Seven icon buttons located along the bottom of the notepad screen issue commands when you touch them with the electronic stylus. Each button triggers different functions, such as the calendar and phone book. While the actual buttons may change before the product is sold, at present they are: Who, What, When, Find, Format, Send, and Assist. Press "Who" to access your address book; "What" opens up your to-do list; "When," your calender; "Find" checks for messages; "Format" turns notes into a business letter; "Send" faxes a letter to a colleague. Confused? Press "Assist" for help.

Touch a certain day or week on the calender with the pen, and that day or week will be highlighted and enlarged to full-screen-size for easier viewing. Draw a square, then scribble out one corner, and that corner is instantly erased. Or write 2 + 4 =, and the answer instantly appears on the screen.

subsystem called HWX which operates in real time at 3 characters per second on a 16-MHZ 286 processor and occupies about 100K bytes of memory; plus, another 100K for a general purpose spelling dictionary of 100,000 words.

> "HWX tolerates characters that overlap, touch, or share strokes, and it handles inconsistent input from the same person." . . . "After a small amount of training, users typically experience accuracy rates of 4 out of 5 words translated correctly, the fifth word having an easily correctable error (ie., a word-level accuracy of 80 percent to 90 percent) this is equivalent to a raw character-accuracy rate of 90 percent to 97 percent." (Carr 1991, 212)

Furthermore, Apple's PDA, *Newton* also has handwriting recognition software which can also apply its recognition abilities to graphic elements drawn by the user:

> "Newt/OS is a multitasking operating system. It can have multiple recognition functions active at the same time. This means that you can create a drawing, using the graphics recognition function and then annotate it with labels, using the handwriting recognition function - all without switching modes. This multiple function interface for jotting notes or sketching diagrams is as natural as using paper." (Ito 1992, 47)

Again, it must be reiterated that PDA's were designed with the consumer in mind and ease of use and user friendliness were the goals of the designers:

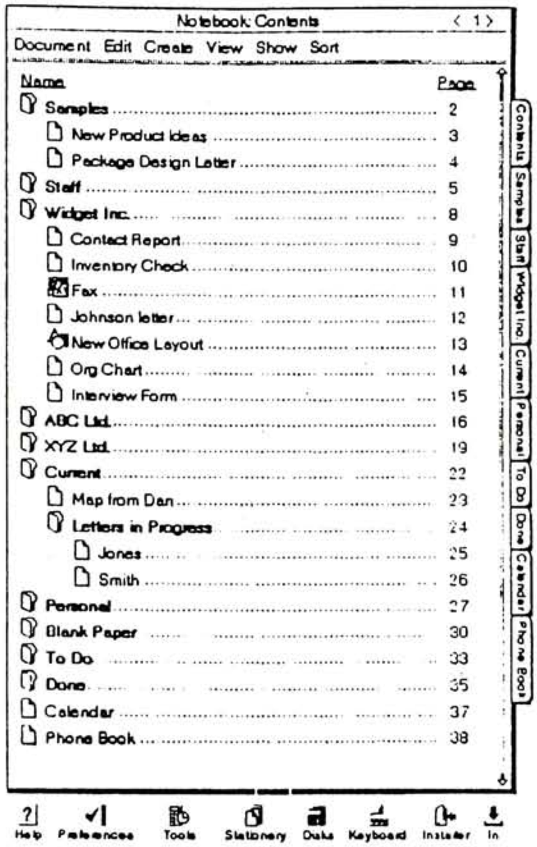
> "Using the system and its controls is difficult to describe, perhaps because it is so natural. The notebook metaphor with tabs and a table of contents is obvious and elegant. Just about the only concept that the user must grasp is that pointing the stylus at something is equivalent to saying 'go right to this'." (Linderholm 1991, 218)

Go's *Pen Point* uses what they call a NUI or (Notebook User Interface), which acts like a table of contents: (see figure 8-2)

> "The notebook metaphor is *Pen Point's* major organizing interface. This interface provides a quick reference style of access where you can find all the information that you need with just a few quick taps of the pen." (Carr 1991, 211)

Fig. 8-2

Screen 1: *The PenPoint notebook user interface. The page number is at the upper right; tapping the pen on it advances the notebook to the next page. To the right are tabs associated with pages or sections of the notebook. At the bottom is the bookshelf; the icons represent various PenPoint services.*



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Furthermore,

> "The *Pen Point* interface, common to all applications, looks like a contents page. Tapping the appropriate icon creates a new page. Handwriting and sketches can be mixed on the main page and keywords jotted in the margin are recognized and converted into 'typed text.' A 20 Mb hard disk of solid state memory allows up to 3000 pages of such notes. To communicate with the outside world, the user places the document in the 'Outbox' and the system automatically sends a fax or printing request when connected to the appropriate facility." (Evans 1992, 89)

And finally, PDA's are compatible with existing computer equipment for example;

> "*Pen Point's* standard for application distribution is 3.5 inch 1.44 Mb MS-DOS floppy disks. Every *Pen Point* capable machine has access to a 3.5 inch floppy disk drive (either built-in, via a base station, or through MS-

DOS desktop PC.). (Carr 1991, 221)

Therefore, each document on file is in itself like a live piece of user data that can be transferred and made available through a multitask operating system designed expressly for the unique needs of a user who is on the move.

In summary, it is fair to say that PDA's will play an increasing role in society, especially in task specific jobs in which standardized forms and paperwork are needed.

> "What's the big deal about a $1000 computer that works like a $2.00 notebook? Professionals have been asking for an electronic notepad that allows them to create information electronically on the go, either for immediate processing or for use back at home base. A boon to sales forces, insurance adjusters and the legions of form fillers, these products will likely find large vertical markets with applications tailored to specific needs." (Evans 1992, 89)

Finally;

> "Paul Saffo, a research fellow at the Institute of the Future in Menlo Park,California, classifies Apple's PDA as an information appliance. 'It's a new product category that combines the information richness we associate with computers with the low cost, convenience, ease of use, and ultra-portability associated with consumer electronics.' he says." (Soviero 1992, 48)

In conclusion, the reader must agree that PDA's are a new and highly innovative product category that will evolve and make consumers more task efficient. PDA's will be marketed as task specific devices in which software and hardware technology will be expanded into all facets of human experience and will fill a wide range of new applications.

9.0 A PREFACE TO DAEDALUS:

The general aviation manufacturers of this country are barely producing

Fig. 8-3

any new or innovative aircraft for the market, due to the incredible costs of product liability insurance and litigation. Moreover, the general aviation aircraft manufacturers that still produce airplanes cannot afford the huge testing and certification costs associated with bringing safer, more efficient, technologically advanced powerplants and airframe designs to consumers. The vast majority of general aviation pilots are flying aircraft that are a decade or more old, aircraft which were designed and FAA certified in the 1940's, 50's or 60's. The technological advances made by NASA's space programs, military defense spending , and the gains made by commercial aviation research and development only seem to trickle down to general aviation products and aircraft; in light of the staggering contributions that general aviation makes to the U.S. economy.

> "According to the Federal Aviation Administration figures, The GA (general aviation) network in this country enplanes approximately 200 million passengers a year, which is three to four times what the commuters carry and one-third the number flown by the large air carriers. Between 1987 and 1989, GA comprised 61% of all U.S. air traffic operations, and air taxi flights totaled another 13% . . . In 1989, GA airplanes logged 35 million hours, twice the number flown by air carriers. Of those hours, 70% were job and tax revenue-generating operations." (Wallace 1993)

However, although these statistics are impressive, what remains constant is the litigation of product liability and a slumping general aviation market, one in which pilots are flying increasingly aged and obsolete equipment in a complex regulatory airspace environment. Pilots have an ever-increasing role as information managers, in which one must monitor and integrate multiple sources of information, while concurrently being responsible for the "stick and rudder" aspects of flight.

The typical private pilot of today flies a number of different models of general aviation aircraft, depending on whether one is training or taking the family or friends on a long cross country flight. Also, the typical pilot most likely rents a plane from a local flying club or FBO (Fixed Base Operator), either of which can offer a wide variety of aircraft makes and models. Although this sounds convenient, pilots are constantly challenged by a hodgepodge of different control arrangements, engine instruments, radio stacks, switch styles, circuit breakers, flap and power controls, and a bevy of other non-standardized equipment that have changed on the same aircraft from one model year to the next-not to mention flying another manufacturers brand or class of aircraft altogether!

Furthermore, the pilot is constantly challenged by his own flight bag in an attempt to compensate for the misgivings of aircraft design. Pilots constantly wrestle for room in cramped cockpit space, in which sectional maps, course plotters, E6B slide rules, airport directories, checklists, aircraft operating handbooks, pencils, clearance notepads, flight logs and aviation headset and intercom wires tangle one like a suffocating vine. Cockpit clutter can swiftly place severe demands and workload on a pilot. Because of these severe demands, the pilot is no longer the information manager flying the airplane, but increasingly becomes a stressed and panic stricken "firefighter" trying to keep up with the demands of flight. Moreover, the pilot progressively can become overwhelmed by his/her predicament, falling behind the operation of the aircraft and setting the stage for missed procedures and pilot error.

9.1 Daedalus: Cockpit Flight Management System

Daedalus is a cockpit flight management system concept in which todays technology is employed and dedicated to the general aviation pilot. The goal of *Daedalus* is to decrease pilot workload, while increasing a pilots performance,

Fig. 9-1

situational awareness and safety. *Daedalus* is a portable system that is adaptive to both pilot and the aircraft being flown. *Daedalus* is designed to provide easy access to informative procedural matters in a format of predictable functions that reduce variability in task oriented situations. *Daedalus* is a pilot tool used to help organize and efficiently manage the general aviation cockpit.

9.2 Daedalus : A brief overview

* *Daedalus* **DOES NOT**:

- Fly the airplane.
- Replace, substitute, or teach common sense.
- Replace experience or recurrent flight training with a competent Certified Flight Instructor (CFI).
- Replace balanced pilot decision-making.
- Evaluate a "Go or No Go" situation.

* *Daedalus* **DOES**:

+ Help a pilot organize the cockpit.
+ Present material and information in a standard format.
+ Reinforce pilot training.
+ Replace many flight bag items that can clutter or distract a pilot in the cockpit.
+ Is a learning tool that can be used to preview or review an aircrafts standard operating procedures (SOP).

9.3 Daedalus: How it Works?

As mentioned earlier, PDA's (Personal Digital Assistants) represent a whole new class of versatile and consumer-friendly products, in which sophisticated multi-tasking operating software, hardware, and superior microprocessor technology are combined in a unique portable package. PDA technology attempts to intuitively adapt the machine to fit human qualities and allows for extremely flexible task-oriented applications. The concept of *Daedalus* is firmly grounded in this emerging technology that PDAs have to offer. The following sub-chapters will deal exclusively with *Daedalus* and will describe in detail the functions and parts of the unit.

9.4 Pen-based LCD Display / HUD Display

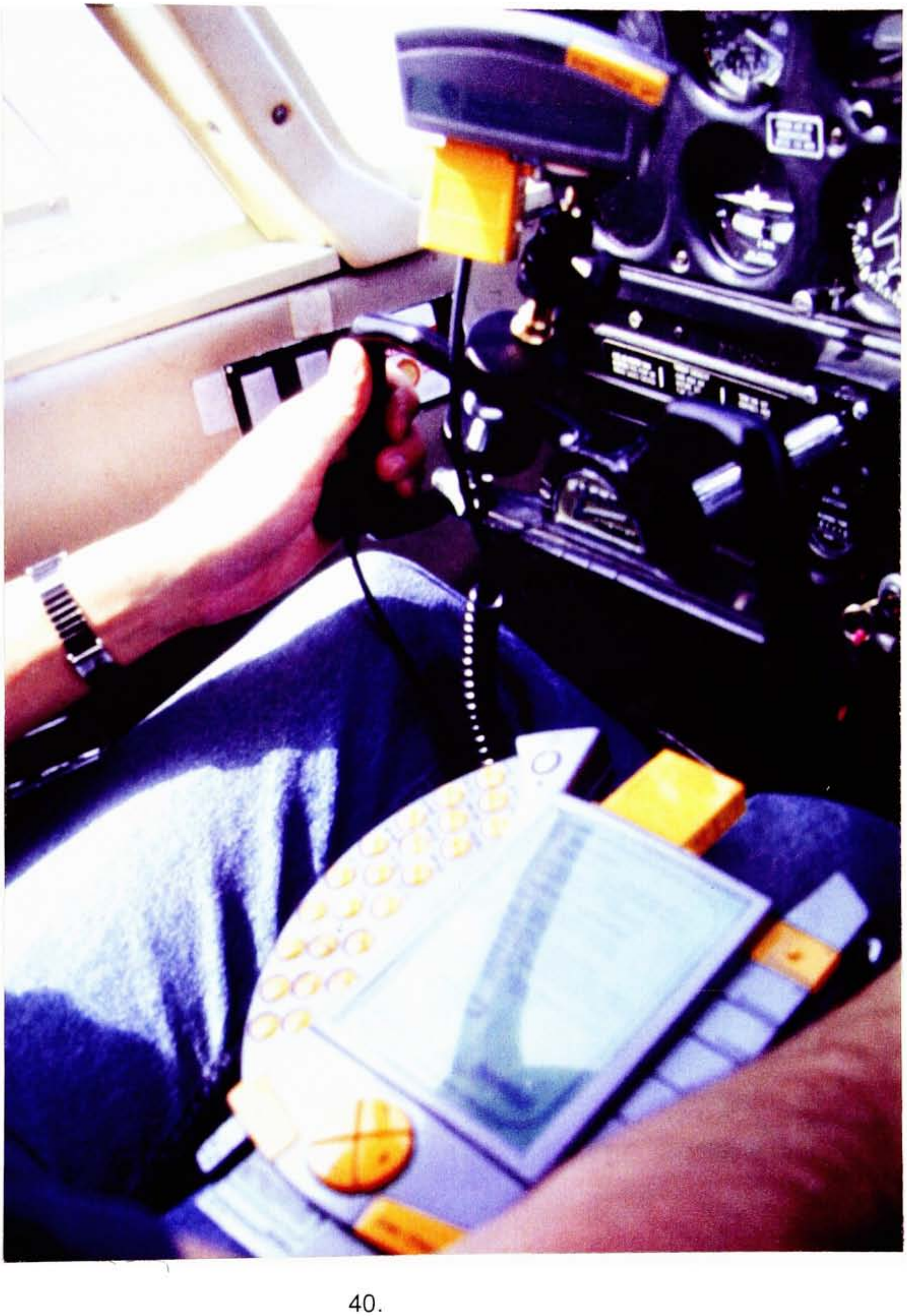
The purpose of any display is to supply information that aids in the process of enhancing human performance. A display is defined as:

> "The deliberate and structured presentation of information to the senses . . . Engineering psychology uses the term in a much more restricted way: Displays present information about the state of the man-machine system."
> (Stokes, Wickens, Kite 1990, 1)

Furthermore, "The purpose of a display in an aircraft is to transfer information about some aspect of the flight accurately and rapidly from its source to the brain of the crew member, where it is processed." (Hawkins 1987, 226) *Daedalus* utilizes two types of backlit liquid crystal display (LCD) screens. The first is the 4" x 5" inch pen-based LCD screen that acts as a multifunctional interactive display tablet. The second LCD screen belongs to the detachable 4" x 3/4" inch heads-up display (HUD) prompter, which is a dedicated task-specific line item display. Both LCD screens work together as a unit, the main pen-based screen providing the whole checklist picture, while the smaller HUD LCD screen provides specific line item commands. The two screens allow a pilot to effectively cross-monitor the specific task at hand, providing the user with system information redundancy while reducing the possibility of errors.

The 4" x5" inch pen-based LCD input screen is located on the main kneeboard unit and utilizes the handwriting recognition software. A pilot can use

Fig. 9-2



the writing stylus and "notebook" flight function key (F5) to write important radio frequencies, air traffic control (ATC) clearances, transponder squawk codes, personal notes and any other information pertaining to the flight as it occurs. The pen-based notebook is accessed by pressing the (F5) flight function key at any time. The notebook is driven by internal RAM supplied by a hard disk drive, which allows you to write, store, and retrieve important notes. The notebook function is driven by the cordless writing stylus and the notebook user interface software and can be turned off by pressing any other flight function keys.

The other function of the pen-based LCD notebook screen is to display the ROM driven aircraft checklist information supplied by aircraft data cards. The ROM-driven aircraft checklist is cued by pressing any of the appropriate flight function keys, which will take a user to checklists for Preflight (F1), Start-up (F2), Run-up (F3), Takeoff (F4), Notebook (F5), Cruise (F6), Landing (F7), Shutdown (F8), and Emergency procedures (F9). The checklist screen itself has twenty-five lines with a maximum of fifty characters per line in easily-read 12 point type.

The pen-based LCD input screen is used to get the "big picture" of the checklist. Prompting is accomplished by pressing either of the yellow Enter/Check buttons. As each item is checked off, the display will tell the user to proceed to the next item until the list ends, after which the screen will advise the user to proceed to the next checklist by pressing the appropriate flight function key. The pilot can prompt at his/her own pace, the unit does not set the pacing of checklist tasks. The pen-based LCD input screen can also be manipulated by the yellow circular four-way cursor control button, which is especially helpful when utilizing the E6B flight performance calculator. In summary, the multifunctional attributes of the pen-based LCD input screen allow a pilot to pace himself/herself at a comfortable speed that is compatible with one's flying experience, while contributing to situational

Fig. 9-3

awareness and allowing for error-free operation and a more evenly distributed workload.

9.5 HUD: Heads-up display

The second backlit LCD display that *Daedalus* utilizes belongs to the detachable heads-up display or HUD. *Daedalus'* heads-up display allows the pilot to mount the dedicated line item LCD display on the yoke, dashboard, or aircraft visor with the use of a universal photo accessory adapter attachment. The HUD is then connected to the main unit through the use of a patch cord, which supplies it with both power and information.

The goal of HUD technology was pioneered, researched, and developed for military use. HUD's goal is to relieve the pilot of unnecessary visual instrument scanning by projecting relevant flight information onto the windshield of the aircraft. In addition, "The HUD in civil aviation was conceived with the objective of easing the transition from head-down flying for visual landing." (Hawkins 1987, 234) Furthermore, HUD promotes a situation in which visual scanning is not required between outside and inside information sources, because all pertinent information is right in front of the pilots field of vision: Technically this concept is referred to as parallel processing. Parallel processing attempts to foster a situation in which,

> "The ability of an operator to process two or more streams of information concurrently, this perception of motion is carried out in this parallel with perception in fovial vision." . . .

Moreover, the fovial vision system is defined as;

> "Being high resolution sight that is concerned with analysis of nature, form and patterning of visual targets, perceived and picked up by the fovea (in the eye structure) as opposed to peripheral vision system that makes up 90% of our sight intake, which is concerned with relative position, motion,

Fig. 9-4

> contextualizing orientation cues, perceived primarily by the peripheral retina." (Stokes, Wickens, Kite 1990, 9-12)

In plain english, the fovial vision of the human eye is like a high-powered telescope, which can focus on a specific object, while the peripheral vision component of the eye is like a camera that is focused for large panoramic visual fields. For example, a pilot while getting a air traffic advisory from a control tower via radio, at the same time will scan the sky using the 90% of his/her peripheral vision looking for movement that may resemble the target plane. Once the pilot has the traffic in sight he/she will target the object using his/her fovial vision to ascertain the plane's speed, direction, altitude, relative position, type of aircraft, and then initiate the proper avoidance control inputs. And finally:

> "The assumption that parallel processing will increase as proximity in the visual field is increased underlies the principle behind the aviation heads-up display . . . It is assumed that superimposing the near visual world should allow parallel processing of both items of information and reduce the need for eye movements to the instrument panel." (Stokes, Wickens, Kite 1990, 10)

The second "intended purpose of HUD projection is, of course to allow the pilot to take in information from the HUD instruments without taking 'eyes-off' the outside scene," (Stokes, Wicken, Kite 1990, 89) which is a definite advantage in avoiding a mid-air collision with another aircraft or a run-in with mountainous terrain.

However, there are disadvantages to the HUD concept. HUD's parallel processing concept can cause problems with sensory overload, in which the field of vision can get excessively cluttered with electronic symbology and the outside world. Another disadvantage of HUD is that the human brain uses serial processing most of the time as it takes in and deciphers data.

> "Serial processing is visual scanning in which parts of the environment scanned sequentially, they fall outside the range

> fovial vision, and the eyes seek different sources of movement and information at appropriate times. In these circumstances, certain objects, stimuli, or events will be attended to and others will be ignored even when neither is filtered at the level of sensory receptors." (Stokes, Wickens, Kite 1990, 5-6)

Moreover;

> "In particular, consistently mapped, automatically processed stimuli may 'pull' attention to them, and therefore disrupt the processing of discrete stimuli that may occur more or less simultaneously; involuntary attention shifts, which automatically diverts full resources of the operator into serial processing." (Stokes, Wickens, Kite 1990, 9)

A pilot of an aircraft in flight must process a wide range of visual and auditory signals and material. Perceptually our minds will allocate attention to the stimuli that is most powerful in most instances.

Of course, the HUD on *Daedalus* is not a costly complex information projection device; however, it is important for the reader to be "brought up to speed" on the concept behind HUD. The HUD on *Daedalus* provides the pilot with a task-specific message and allows the user to quickly access a checklist item line by line, while lessening dwell time in the cockpit. If a pilot should get distracted from the HUD, he/she can easily look down to the pen-based input screen and cross-reference the checklist from where he/she left off. Redundancy through cross monitoring is the goal of *Daedalus'* HUD, which seeks to get the pilot's eyes up out of his/her lap and puts one's peripheral vision to use.

Daedalus' LCD display screen itself measures 4" x 3/4", which allows for 2 lines with a maximum of 28 characters per line in 24 point type for easy reading. The HUD LCD screen also includes a backlighting mechanism to enhance readability in most lighting conditions. However, backlighting is the main source of power consumption in LCD's, but similar devices in use today have timers that turn

Fig. 9-5

LCD backlights off to save batteries after 30-45 seconds of inactivity.

9.6 Data Cards

Daedalus aircraft checklists operate with the use of preprogrammed data cards.The data cards empower *Daedalus* with a particular aircraft's checklists, standard operating procedures (SOP) and emergency procedures in a convenient format. *Daedalus* users would need to specify year, make and model of the aircraft being flown. *Daedalus* users could also conceivably have a customized data card programmed for his/her specific aircraft checklist criteria. For redundancy and back-up, each data card would be accompanied by a plastic laminated paper checklist in case *Daedalus'* batteries go dead or the unit fails in-flight. Another feature that could be added to the data card could list information pertaining to any FAA airframe or powerplant Airworthiness Advisories that a pilot might need to know about.

The data cards measure 1 7/8" x 2 1/2" x 1/8" in size. Each card is clearly labeled and is stamped with optical bar coding that will make it easy for the manufacturer to keep track of the information supplied on the card. The data card slips into the front of the main unit. Once the unit is powered-up, the green data card indicator light tells the user that a good connection has been made. Another advantage of placing the data card port facing the user is that one's body can help keep the data card from getting knocked out of place. Changing from one aircraft data card to another is as simple as pushing the data card ejection button and sliding in another one.

9.7 E6B Flight Performance Calculator

Daedalus also incorporates an electronic E6B flight performance calculator. The

Fig. 9-6

calculator is designed to perform nineteen aviation calculations and fourteen standard aviation conversions with a high degree of accuracy. Solving any navigational, weight- and-balance, or fuel endurance problem is convenient and fast. Using the yellow circular four-arrow cursor control button for simple menu selection, the large easy-to-read pen-based input screen doubles as a calculator worksheet. Information is automatically retained for future use in "chain calculations". Advanced timer functions lets the user count up or down while timing flight distance legs and operates independently so other calculations can be performed. The flight calculator also performs conventional mathematical problems. Moreover, the advantages over conventional slide rule type E6B flight computers saves time and let's pilots get their performance values quickly, thus freeing the flight for more pressing needs.

9.8 Power Requirements

Daedalus would come ready for operation with an alkaline battery pack of six "AA" batteries, producing nine volts of power. Battery life would be approximately 6-8 hours in normal use and 5-7 hours with the LCD backlight on, which is typical for electronic devices of this size and power in today's marketplace. *Daedalus* could also be run on a rechargeable battery pack of nickel cadmium batteries, however, battery life would be approximately 2.5-3.5 hours in normal use and about 2 hours with the LCD backlight display operating. In addition, *Daedalus* could be operated by an auxiliary power source supplied by a nine volt cigarette lighter adapter power cord which plugs into the unit. The use of both battery power and a cigarette lighter adapter offers two types of power supply redundancy.

Fig. 9-7

9.9 Kneeboard

Daedalus was designed with pilots in mind. The vast majority are very familiar and comfortable with using conventional pilot kneeboards. Pilot's kneeboards offer superior comfort and utility in organizing maps, checklists, approach plates, flight logs or other information that is pertinent to conducting a flight. Pilot's kneeboards are available in many pilot catalogs, come in many configurations, styles, offering different features and are priced to suit any skill level.

The kneeboard for *Daedalus* is made of a combination of light weight, durable, injection molded ABS (Acrylonitrile-Butadiene-Styrene) with a sponge lined saddle that is ergonomically contoured to fit the shape of the users leg. A wide elastic nylon strap mated with a quick-snap buckle assures a secure comfortable fit. The kneeboard is attached to the bottom of *Daedalus* by two mounting screws.

Daedalus was designed to be used with a kneeboard because it is an already acceptable method of organizing and mounting material in the cockpit. The advantages of kneeboards are clear, they offer ergonomic flexibility for people of all sizes, accommodate either sex, are portable, user-ambidextrous, and don't have to be hard- mounted in the cockpit.

10.0 MATERIALS AND MANUFACTURE.

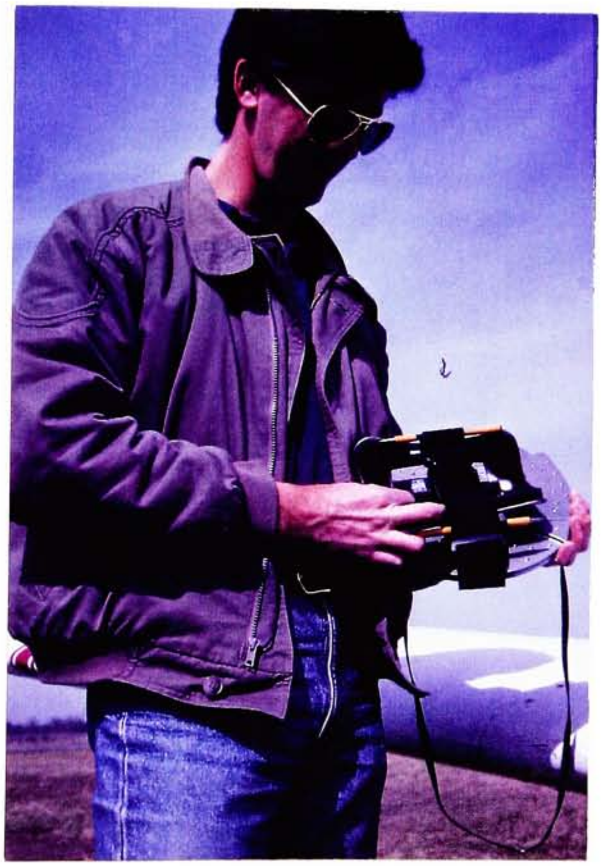
The architecture and design of *Daedalus* make it a good candidate to be manufactured out of injection molded ABS. ABS is an excellent choice of materials because of its durability and ability to capture fine surface detail. ABS is classified as a thermoplastic resin, its properties include:

"Basically a styrene that has been modified for strength

Fig. 9-8

Fig. 9-9

Fig. 9-10



> and toughness greater than normal styrene. Wide range of formulations available, some with excellent toughness to -60 degrees Fahrenheit; temperature resistance up to 212 degrees Fahrenheit possible; good resistance to acids, alkalis and salt; good electrical properties. High gloss and unlimited color range possible, including transparent. Electroplating grade for chrome plating also available. Used for pipe housewares, helmets, shoe parts, office equipment, luggage, battery cases, etc." (Hoogesteger 1987, 83)

ABS is an appealing resin because it allows designers to get detailed durable parts with injection molding. For example:

> "What appearance characteristics do you associate with hair dryer covers, telephones, pocket combs, childrens' toys, and stereo head phones? Most of us would list smooth finish and high gloss, fine detail, integral color, light weight, and comfortable feel . . . Injection molding is to plastics materials as die casting is to non-ferrous metals. For considerations of draft, parting line location, undercuts, and the inclusions of as many functions as possible in a single part, the designer can think of the two processes interchangeably. Injection molding produces parts at a high rate through the use of very accurate, hardened steel molds that are opened and closed, filled with molten material, and designed to automatically eject the finished part." (Hoogesteger 1987, 62)

Button details for *Daedalus* could be made of thermoplastic rubber, in which symbology could be printed on the parts by pad transfer printing. *Daedalus* was designed for ease of assembly; construction of the unit is from the bottom up. Ancillary electronics can be screwed or snapped into the ABS shell, and sandwich construction with the top half completes the picture. Injection-molded parts keep the number of parts to a minimum, make for ease of assembly and make it easy to fasten and incorporate all internal components.

10.1 Daedalus Design Aesthetics

One of the toughest jobs a designer must face is the uncompromising task of balancing form and function into an aesthetically pleasing and usable article. A truly successful design incorporates exceptional human factors in a form that is functional, durable, user-friendly and memorable.

Daedalus' form is one of simple asymmetry, which provides the pilot with a clear picture of the task at hand. The asymmetrical design design allows a pilot tactile reference on the workstation without having to look down first. The E6B flight performance calculator's shape is round and is a metaphor of conventional aviation slide rule calculators. Another example of a tactile cue, allows the pilot, in the event of an inflight emergency, to slide a hand or finger up the flight function prompt keys until he/she runs up against the yellow "Emergency procedures" key (F9), which has a distinctive bump on it. The advantage of this type of tactile cue allows the pilot to keep "head-up and eyes out the window" until he/she is ready to access the Emergency Procedure information.

Important control buttons are colored in high-contrast yellow with black letters, which allow for easy readability in a wide range of lighting conditions. Flight function keys are arranged in a logical relationship, which starts with preflight and ends in shutdown procedures. The overall layout of the controls provides for optimum use and user-friendliness. *Daedalus'* software would be designed and written to supersede miscues or prompts, if multiple buttons are being pushed at the same time. User-friendly software is designed in a "if" and "then" proposition, in which the software anticipates correct prompts and inputs, thus rewarding the user with valid output. Another goal that the software and hardware must fulfill is that it must allow the user to reverse any input errors that could lead to serious consequences. For example, if a checklist item was skipped, or is being dwelled upon, the software could blink and ask the user "Are you sure?" All systems, whether hard or soft, must allow for flexibility and should accommodate human

Fig. 10-1

error if safety is to be assured.

The physical size of *Daedalus* is 10" x 7 3/4" x 1 1/4" which is a touch larger than most conventional kneeboards. However, *Daedalus* although mounted on a kneeboard allows for ample air circulation for both the pilot and the unit. On the underside of the HUD and main unit, *Daedalus'* housing is pebbled with courtesy bumps that provide the user with sure-handed gripping power.

The overall housing of *Daedalus* is colored in a conservative light gunmetal gray metallic finish. The conservative finish denotes an aesthetic of professionalism, efficiency, separation of task, and implied ease of use. LCD data screens are spacious and flush mounted to their respective housings for a smooth clean finish. Parting lines are deliberate, crisp and in close tolerances of each other. The entire design aesthetic of *Daedalus* seeks to meld form and function into a attractive, tight knit, and efficient package.

11.0 CONCLUSION.

"There are Old Pilots and there are Bold Pilots, but there are no Old Bold Pilots. Will we see you at the next Meeting?" (Old QB "Quiet Birdman" saying)

The thesis concept for *Daedalus:* Cockpit Flight Management System is firmly grounded in the study of human factors. Human factors at its most basic level is about four things:

A) People.
B) People and their relationships to others.
C) People in their living and working environments.
D) People's relationships with machines, equipment, and procedures in the environment about them.

(Hawkins 1987, 18)

Public attention will always be tightly focused on aviation and aircraft accidents. If pilot error is to blame in approximately 80 percent of all aviation accidents, it is time to study, research, and implement training programs and tools to improve pilot performance and make flying safer. However, we must take heed in the fact that:

> "Individual aspects of the flight deck should not be evaluated in isolation. The flight deck must be seen as a system with the liveware, hardware, software and environment as its components." (Hawkins 1987)

Aviation safety research must study both the human component along with the machine in the environment in which they operate. The problem of human error will never leave the human race; remembering "to be human is to err," but failure to learn from one's mistakes only compounds suffering and unsafe attitudes.

> "In aviation, experience is the result of non-fatal mistakes! And that's true, we all make mistakes. The point is that an experienced pilot has corrected his errors before they killed him; time after time, but he doesn't make the same mistake twice." (Assenheim and Bell 1990, 112)

In addition:

> "Until the airman, who naturally is subject to human error, is no longer the determining factor, the utmost in dependability and safety cannot be assured. In the final analysis, no matter how much engineering talent has been applied to the development of an air transport as a machine alone, the aircraft is safe and dependable only to the degree that its control does not exceed the abilities of the pilots who fly it." (Mc Farland 1946, 1)

The nucleus of aviation safety is quite simple, a problem that is recognized and dealt with early by a pilot or crewmember rarely results in a error or accident. *Daedalus* seeks to format aircraft procedures and checklists into a predictable system that reduces pilot workload, while enhancing one's situational awareness, decision-making, and overall safety. Again, it is important to reiterate the the thesis statement that lead to the *Daedalus* concept:

> "The purpose of this thesis was to design a portable computer based flight management system for general aviation pilots. The idea of *Daedalus* arose from the need to ease pilot workload and help organize the cockpit more efficiently, thus promoting safety and reducing pilot error."

And on a final note:

> "Eddie Rickenbacher, America's top Ace in WWI and later founder of Eastern Airlines, once said. . .When I fly on one of my airliners now, I sit back with the passengers. But I like to look around the cabin and observe the passengers. I see a little old lady who is nervous and fidgeting around, and I can see that she is a first time air traveler; Then I see a businessman with his briefcase open working on his papers, and he is obviously a seasoned air traveler; Then I look down the aisle and see a man passionately chewing, gnawing, and biting his fingernails off; that tells me that man's a pilot! And he's not in control!" (Assenheim and Bell 1990, 112)

In summary, *Daedalus* is a product concept whose time has come. Pilots should stop "gnawing at their fingers" worrying about being in control; the technology exists to put the pilot in greater command of his destiny and aircraft by flying smarter, safer, and better informed.

Fig. 11-1

The End

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Appendix A: Thesis Exhibition

Fig. A-1

Fig. A-2

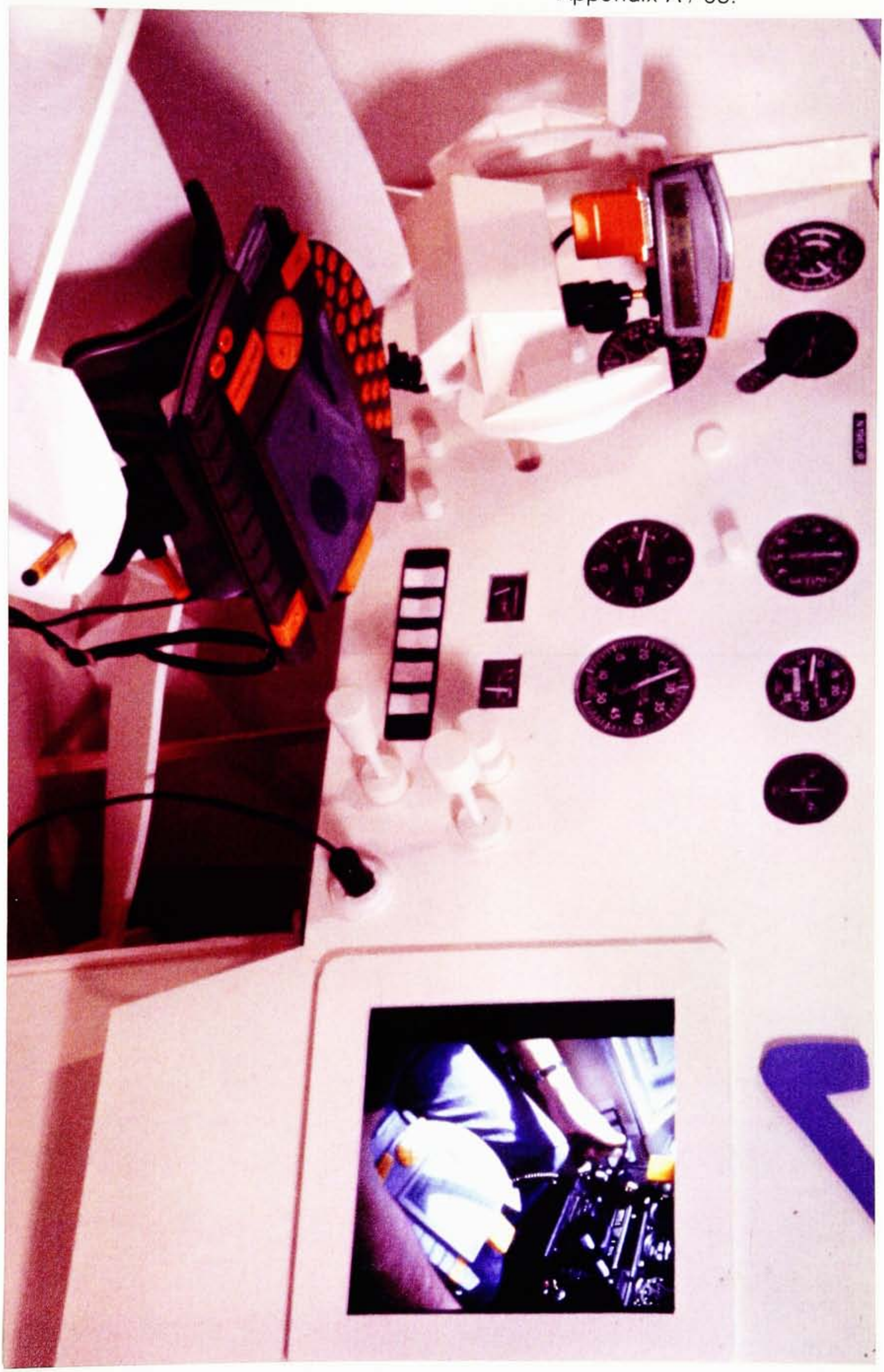


Fig. A-3

Fig. B-1

Appendix B: AOPA's 1993 Aviation Fact Card

AOPA'S 1993 AVIATION FACT CARD

Aircraft Owners and Pilots Association
421 Aviation Way, Frederick, Maryland 21701
301/695-2000 or 800/USA-AOPA

Primary sources of data include the Federal Aviation Administration, the National Transportation Safety Board, the General Aviation Manufacturers Association, and others. 1991 is the latest year complete information is available.

1991 DATA

ACTIVE CERTIFICATED PILOTS

	Total	%	Women*	%
Pilot Certificates Held	692,095	100.0	40,931	100.0
Student	120,203	17.4	14,501	35.4
Recreational	161	—	15	—
Private	293,306	42.4	17,514	42.8
Commercial	148,365	21.4	5,652	13.8
ATP	112,167	16.2	2,308	5.6
Helicopter (only)	9,860	1.4	307	0.8
Glider (only)**	8,033	1.2	634	1.5
Flight Instructor	69,209	10.0	3,629	8.9
Instrument Rated	303,193	43.8	NA	—
Helicopter (total)	32,605	4.7	NA	—
Glider (total)	19,570	2.8	NA	—
Non-Pilot Certificates Held	517,462	100.0	10,324	100.0
Mechanic	366,392	70.8	3,901	37.8
Parachute Rigger	7,916	1.5	363	3.5
Ground Instructor	70,086	13.5	3,952	38.3
Dispatcher	11,607	2.2	852	8.3
Flight Navigator	1,225	0.2	0	0.0
Flight Engineer	60,236	11.6	1,256	12.2

* 5.9% of all pilots are women

** Medical examinations not required, totals represent only pilots who have a current medical and have no other pilot certificate

NA = Not Available

ACTIVE CIVIL AIRCRAFT

	Total	%	%
Total Aircraft	204,529	100.0	100.0
Piston	175,630	85.9	—
Turboprop	6,518	3.2	—
Turbojet	8,520	4.2	—
Rotorcraft	6,298	3.1	—
Other	7,563	3.7	—
General Aviation Aircraft	198,475	100.0	97.0
Piston, Single-engine	154,102	77.6	—
Piston, Multiengine	21,119	10.6	—
Piston, Other	126	0.1	—
Turboprop	4,920	2.5	—
Turbojet	4,353	2.2	—
Rotorcraft	6,292	3.2	—
Other	7,563	3.8	—
Air Carrier Aircraft	6,054	100.0	3.0
Piston	283	4.7	—
Turboprop	1,598	26.4	—
Turbojet	4,167	68.8	—
Rotorcraft	6	0.1	—

U.S. AIRCRAFT SHIPMENTS

	Total	%	%
Total Aircraft Shipments	2,181	100.0	—
General Aviation	1,021	46.8	100.0
Single-engine	564	—	55.2
Multiengine	49	—	4.8
Turboprop	222	—	21.7
Turbojet	186	—	18.2
Helicopter	571	26.2	—
Air Transport	589	27.0	—

ESTIMATED AVERAGE PER-UNIT COST OF NEW AIRCRAFT

Aircraft Type	$
Piston Aircraft (single-/multiengine)	151,700
Turboprop	2,373,900
Turbojet	7,247,300

GENERAL AVIATION AVIONICS EQUIPMENT ESTIMATES

	Total	%
Total Active General Aviation Aircraft	198,475	100.0
With Electrical System	189,942	95.7
Without Electrical System	8,533	4.3
VHF Communications		
360 Channel Fixed	65,787	33.1
720 Channel Fixed	138,829	69.9
No VHF Communication	16,887	8.5
Transponder Equipment		
Mode A Transponder	13,176	6.6
Mode C Transponder	163,100	82.2
Mode S Transponder	1,174	0.6
No Transponder	41,206	20.8
Precision Approach Equipment		
Localizer	128,166	64.6
Marker Beacon	120,950	60.9
Glideslope	117,335	59.1
No Precision Approach Equipment	77,096	38.8
Navigation Equipment		
100 Channel Fixed VOR	52,128	26.3
200 Channel Fixed VOR	123,473	62.2
ADF	118,657	59.8
DME	82,900	41.8
RNAV	30,601	15.4
Loran C	103,166	52.0
Loran C (VFR only)	84,735	42.7
Loran C (IFR Navigation)	13,745	6.9
Omega	3,361	1.7
Radar Altimeter	18,542	9.3
Weather Radar	21,799	11.0
Thunderstorm Detector	18,205	9.2
GPS System	2,915	1.5
No Navigation Equipment	28,022	14.1
Guidance/Control Equipment		
Flight Director	22,105	11.1
Autopilot—Longitude	69,449	35.0
Autopilot—Vertical	46,130	23.2
Autopilot—Lateral	57,909	29.2
Autopilot—Approach Mode	42,713	21.5
No Guidance/Control Equipment	134,335	67.7

ACTIVITY ESTIMATES

	Total	%
Hours Flown (Millions)	47.3	100.0
General Aviation	30.1	63.6
Air Carrier*	17.2	36.4
Miles Flown (Millions)	9,048.1	100.0
General Aviation	3,918.1	43.3
Air Carrier**	5,130.0	56.7
Departures (Millions)	58.5	100.0
General Aviation	48.0	82.1
Air Carrier**	10.5	17.9
Passengers (Millions)	572.2	100.0
General Aviation***	120.0	21.0
Air Carrier****	452.2	79.0
Fuel Consumed (Million Gallons) @	16,694.0	100.0
General Aviation	1,037.0	6.2
Air Carrier	15,657.0	93.8
Avgas	340.0	2.0
Jet Fuel	16,354.0	98.0

* Includes U.S. scheduled and unscheduled Part 121 and Part 135 operators

** Includes U.S. scheduled and unscheduled Part 121 operators and scheduled Part 135 operators

*** Based on 2.5 passengers per general aviation departure

**** Includes U.S. scheduled Part 121 operators only

@ Estimated

1991 DATA

U.S. AIRPORTS

	Total	%	%
Aircraft Landing Facilities	17,581	100.0	100.0
Airports	12,904	73.4	--
Heliports	4,199	23.9	—
STOLports	70	0.4	—
Seaplane Bases	408	2.3	—
Publicly Owned	5,090	—	29.0
Privately Owned	12,491	—	71.0
Public Use	5,551	—	31.6
Limited Use	12,030	—	68.4
Airline-served	666	100.0	3.8
Scheduled	388	58.3	2.2
Unscheduled	278	41.7	1.6
Longest Runway			
Less than 3,000 ft	11,823	—	67.2
Between 3,000 ft and 5,999 ft	4,807	—	27.3
Between 6,000 ft and 9,999 ft	715	—	4.1
10,000 ft or more	236	—	1.3
1991 Landing Facilities Abandoned	387	100.0	—
Public Use	38	9.8	—
Limited Use	349	90.2	—

TEN BUSIEST U.S. AIRPORTS (FY)

Airport	Total Operations	General Aviation Operations	%
Chicago O'Hare	808,759	30,577	3.8
Dallas/Ft. Worth	731,070	15,860	2.2
Los Angeles Int'l	660,680	53,371	8.1
Atlanta Int'l	639,698	19,160	3.0
Santa Ana	550,602	453,762	82.4
Van Nuys	511,281	510,281	99.8
Phoenix Sky Harbor	499,157	117,857	23.6
Denver Stapleton	491,275	34,058	6.9
Miami Int'l	481,709	73,200	15.2
Long Beach	461,244	427,214	92.6

AERONAUTICAL FACILITIES

Air Route Traffic Control Centers	24
Air Traffic Control Towers	691
IFR Towers	254
VFR Towers	433
Cerap/Tracon Towers	4
Radar Approach Control Facilities	240
Instrument Landing Facilities	1,188
Full ILS	928
Partial ILS	204
Localizer Directional Aid (LDA)	21
Microwave Landing System (MLS)	5
Simplified Directional Facility (SDF)	30
VOR/Vortac Facilities	1,045
Nondirectional Beacons (NDBs)	1,325
Direction Finders (DFs)	116
Flight Service Stations (FSSs)	175
International Flight Service Stations (IFSSs)	3

TRANSPORTATION FATALITIES

(Preliminary Data as of September 10, 1992)

	Fatalities	%
Total Transportation Fatalities	43,631	100.0
Highway	41,150	94.3
Aviation	941	2.2
Marine	924	2.1
Railroads	602	1.4
Other	14	—

CIVIL AVIATION ACCIDENT DATA

(Preliminary Data as of January 17, 1992)

	Total	%
Total Accidents	2,276	100.0
General Aviation	2,143	94.2
Air Carrier*	133	5.8
Total Fatal Accidents	452	100.0
General Aviation	414	91.6
Air Carrier*	38	8.4
Total Fatalities	942	100.0
General Aviation	746	79.2
Air Carrier*	196	20.8

	Total Accidents	Fatal Accidents
Rate per 100,000 Hours Flown**	4.75	0.94
General Aviation	6.97	1.35
Air Carrier*	0.77	0.22
Rate per 100,000 Departures***	3.89	0.77
General Aviation	4.46	0.86
Air Carrier*	1.27	0.36

* Includes air carrier (scheduled and unscheduled), commuter, and air taxi accident data

** Based on NTSB estimated data (30.76 million hours flown by Part 91 operators and 17.20 million hours flown by the air carriers)

*** Based on FAA (48.0 million general aviation departures) and NTSB estimated data (10.5 million air carrier and scheduled commuter departures)

PRELIMINARY/ ESTIMATED 1992 DATA

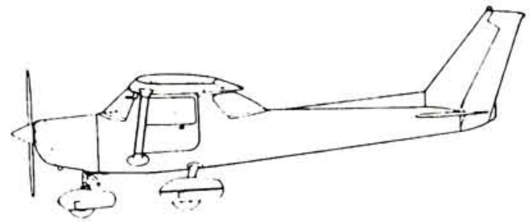
	Total	%
Pilot Certificates Held	699,800	100.0
Student	121,500	17.4
Private	293,300	41.9
Commercial	150,600	21.5
ATP	115,800	16.5
Instrument Rated	306,800	43.8
Active General Aviation Aircraft	98,700	100.0
Piston, Single-engine	154,000	77.5
Piston, Multiengine	21,200	10.7
Turboprop	5,000	2.5
Turbojet	4,500	2.3
General Aviation Hours Flown (Millions)	29.9	—

THE PAST—1981, 1986, vs. 1991

	1981	1986	1991	% Change from 1981
Pilot Certificates Held	764,182	709,118	692,095	-9.4
Active General Aviation Aircraft	213,226	205,300*	198,475	-6.9
General Aviation Aircraft Shipments	9,457	1,495	1,021	-89.2
Total Aircraft Landing Facilities	15,476	16,582	17,581	13.6
Public-use Landing Facilities	6,290	5,775	5,551	-11.7
General Aviation Hours Flown (Millions)	40.7	31.8*	30.1	-26.0
General Aviation Total Accidents**	3,500	2,576	2,143	-38.8
General Aviation Fatal Accidents**	654	473	414	-36.7
General Aviation Fatalities**	1,282	965	746	-41.8

* Revised downward by the FAA about 7% to reflect new FAA estimation procedures used to produce 1991 data

** 1991 data is preliminary



CESSNA AIRCRAFT COMPANY

1980 MODEL 152

CESSNA AIRCRAFT COMPANY
WICHITA, KANSAS, USA

THE REPRINTING OF THIS MANUAL INCORPORATES INFORMATION ISSUED IN REVISION 1 DATED 11 MARCH 1983 FROM THE PILOT'S OPERATING HANDBOOK AND FAA APPROVED AIRPLANE FLIGHT MANUAL.

Member of GAMA

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PERFORMANCE - SPECIFICATIONS

*SPEED:		
Maximum at Sea Level		110 KNOTS
Cruise, 75% Power at 8000 Ft		107 KNOTS
CRUISE: Recommended lean mixture with fuel allowance for engine start, taxi, takeoff, climb and 45 minutes reserve.		
75% Power at 8000 Ft	Range	320 NM
24.5 Gallons Usable Fuel	Time	3.1 HRS
75% Power at 8000 Ft	Range	545 NM
37.5 Gallons Usable Fuel	Time	5.2 HRS
Maximum Range at 10,000 Ft	Range	415 NM
24.5 Gallons Usable Fuel	Time	5.2 HRS
Maximum Range at 10,000 Ft	Range	690 NM
37.5 Gallons Usable Fuel	Time	8.7 HRS
RATE OF CLIMB AT SEA LEVEL		715 FPM
SERVICE CEILING		14,700 FT
TAKEOFF PERFORMANCE:		
Ground Roll		725 FT
Total Distance Over 50-Ft Obstacle		1340 FT
LANDING PERFORMANCE:		
Ground Roll		475 FT
Total Distance Over 50-Ft Obstacle		1200 FT
STALL SPEED (CAS):		
Flaps Up, Power Off		48 KNOTS
Flaps Down, Power Off		43 KNOTS
MAXIMUM WEIGHT:		
Ramp		1675 LBS
Takeoff or Landing		1670 LBS
STANDARD EMPTY WEIGHT:		
152		1109 LBS
152 II		1142 LBS
MAXIMUM USEFUL LOAD:		
152		566 LBS
152 II		533 LBS
BAGGAGE ALLOWANCE		120 LBS
WING LOADING: Pounds/Sq Ft		10.5
POWER LOADING: Pounds/HP		15.2
FUEL CAPACITY: Total		
Standard Tanks		26 GAL.
Long Range Tanks		39 GAL.
OIL CAPACITY		6 QTS
ENGINE: Avco Lycoming		O-235-L2C
110 BHP at 2550 RPM		
PROPELLER: Fixed Pitch, Diameter		69 IN.

*Speed performance is shown for an airplane equipped with optional speed fairings, which increase the speeds by approximately 2 knots. There is a corresponding difference in range, while all other performance figures are unchanged when speed fairings are installed.

The above performance figures are based on the indicated weights, standard atmospheric conditions, level hard-surface dry runways and no wind. They are calculated values derived from flight tests conducted by the Cessna Aircraft Company under carefully documented conditions and will vary with individual airplanes and numerous factors affecting flight performance.

CESSNA
MODEL 152

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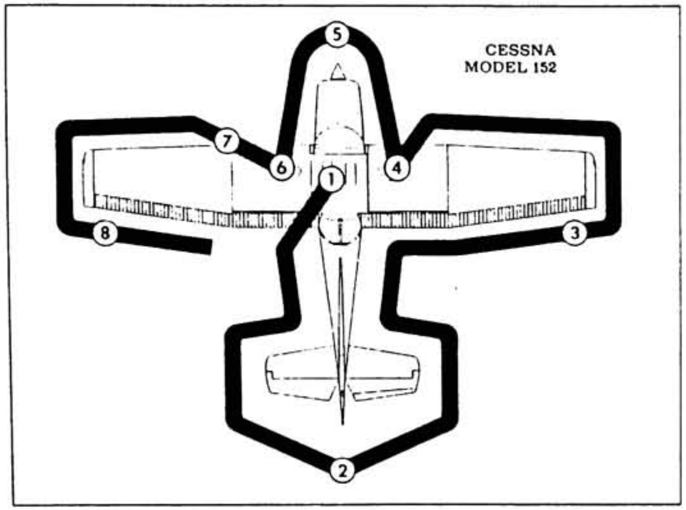
Preflight Inspection:



Note

Visually check airplane for general condition during walk-around inspection. In cold weather, remove even small accumulations of frost, ice of snow from wing, tail and control surfaces. Also, make sure that control surfaces contain no internal accumulations of ice or debris. Prior to flight, check that pitot (if installed) is warm to touch within 30 seconds with battery and pito heat switches on. If a night flight is planned, check operation of all lights, and make sure a flashlight is available.

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Preflight Inspection:

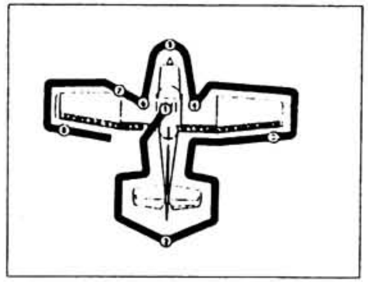
(1) Cabin:

1. Pilot's Operating Handbook - - ***In Aircraft***
2. Control Wheel Lock - - ***Remove***
3. Ignition Switch - - ***Off***
4. Master Switch - - ***On***

Warning

When turning on the master switch, using an external power source, or pulling the propeller through by hand, treat the propeller as if the ignition switch were on. Do not stand, nor allow anyone else to stand, within the arc of the propeller, since a loose or broken wire, or a component malfunction, could cause the propeller to rotate.

5. Fuel Quantity Indicators - - ***Check Quantity***
6. Master Switch - - ***Off***
7. Fuel Shutoff Valve - - ***On***



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(2) Empennage

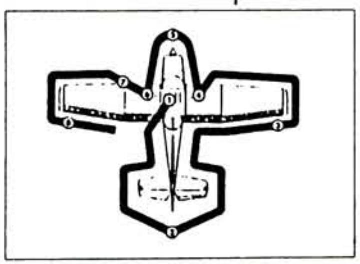
1. Rudder Gust Lock - - ***Check freedom of movement and security***
2. Tail Tie Down - - ***Remove***
3. Control Surfaces - - ***Disconnect***

(3) Right wing Trailing Edge

1. Aileron - - ***Check freedom of movement and security***

(4) Right Wing

1. Wing Tie-Down - - ***Disconnect***
2. Main Wheel Tire - - ***Check-Proper Inflation***
3. Fuel Tank Sump - - ***Drain Fuel Sump Valve - Check for Water, Sediment, Proper Fuel Grade***
4. Fuel Quantity - - ***Check Visually for level***
5. Fuel Filler Cap - - ***Secure***



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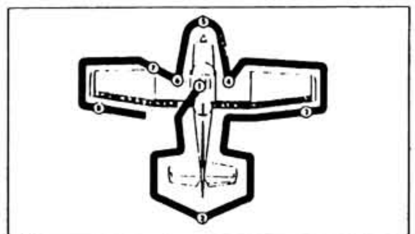
(5) Nose

1. Engine Oil Level - - ***Check Dipstick - No less than 4 Qts. 6 Qts. Max.***
2. Carburetor Fuel Strainer - - ***Pull out Fuel Strainer Knob (4 Sec.) for possible Water and Sediments***
3. Propeller and Spinner - - ***Check for Nicks and Security***
4. Carburetor Air Filter - - ***Check debris, dust, restrictions, Foreign Matter***
5. Landing Lights - - ***Condition / Cleanliness***
6. Nose Wheel Strut / Tire - - ***Proper inflation / Oleo Strut Assembly***
7. Nose Tie Down - - ***Disconnect***
8. Static Source Opening - - ***Check for Stoppage (left side fuselage)***



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(6) Left Wing

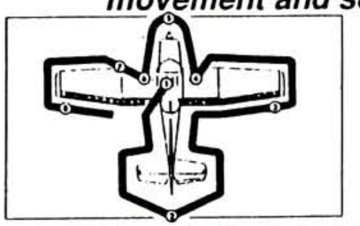
1. Wing Tie-Down - - ***Disconnect***
2. Main Wheel Tire - - ***Check-Proper Inflation***
3. Fuel Tank Sump - - ***Drain Fuel Sump Valve - Check for Water, Sediment, Proper Fuel Grade***
4. Fuel Quantity - - ***Check Visually for level***
5. Fuel Filler Cap - - ***Secure***

(7) Left Wing Leading Edge

1. Pitot Tube Cover - - ***Remove / Check for Stoppage***
2. Stall Warning - - ***Check for Stoppage Apply Suction for Warning Horn***
3. Fuel Tank Vent - - ***Check for Stoppage***
4. Wing Tie-Down - - ***Disconnect***

(8) Left Wing Trailing Edge

1. Aileron - - ***Check freedom of movement and security***



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Interior Inspection:

"ARROW" : Airworthiness
Registration
Radio certificate
Operators manual
Weight & Balance

1. Control Lock - - ***Remove***
2. Radios/Electric - - ***Off***
3. Master Switch - - ***On***
4. Fuel Quantity - - ***Check***
5. Flaps - - ***Extend***
6. Master Switch - - ***Off***

Before Starting Engine :

1. Preflight Inspection - - ***Complete***
2. Seats, Belts, Shoulder Harnesses - - ***Adjust & Lock (Passengers)***
3. Fuel Shut-off - - ***On***
4. Radio, Electrical Equipment - - ***Off***
5. Circuit Breakers - - ***Check In***
6. Brakes - - ***Test & Hold***

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Starting Engine :

(Tempertures above Freezing)

1. Mixture - - ***Rich***
2. Carburetor Heat - - ***Cold (in)***
3. Prime (as required) - - ***0-1 if Hot / 2-3 if Cold***
4. Throttle - - ***open 1 / 4 inch***
5. Propeller - - ***CLEAR PROP / Area ! ! !***
6. Master Switch - - ***On***
7. Ignition Switch - - ***Start (release when engine starts)***
8. Throttle - - ***Adjust (1000 rpm of less)***
9. Oil Pressure - - ***Check (in the green)***
10. Beacon Light - - ***On***
11. Navigation Lights - - ***On***
12. Mixture - - ***Lean one inch***
13. Fuel gauges - - ***Check***
14. Ammeter - - ***Charging***
15. Radios - - ***On***
16. Transponder - - ***Standby (1200)***

16\. Flaps - - ***Up:***

ATIS, Clearance Delivery, & Ground for Taxi Instructions

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Pre-Takeoff Run-Up :

1. Brakes - - ***Hold***
2. Cabin Doors - - ***Closed***
3. Flight Controls - - ***Free & Correct***
4. Elevator Trim - - ***Takeoff***
5. Fuel Shutoff Valve - - ***On***
6. Mixture - - ***Rich (Below 3000 ft. DA)***
7. Flight Instruments - - ***Set***
8. Throttle - - ***1700 RPM***
   a. Magnetos - ***Check - (Max. Drop 125 on either Magneto or 50 RPM differential between Magnetos)***
   b. Carburetor Heat - ***Check RPM Drop***
   c. Engine Instruments - ***In the GREEN***
   d. Ammeter - ***Charging***
   e. Suction Gauge - ***Check (4.5 - 5.4)***
   f. Throttle - ***Adjust (1000 RPM of less)***
9. Radio - - ***Set Tower frequency***
10. Transponder - - ***On, ALT, Test***
11. Lights - - ***As required***
12. Throttle Friction Lock - - ***Adjust***
13. Brakes - - ***Release***
14. Take-off Time ! ! !

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Normal Takeoff:

1. Wing Flaps - - ***0 - 10 Degrees***
2. Carbureator Heat - - ***Cold (in)***
3. Throttle - - ***Full Open (in)***
4. Elevator Control - - ***Lift Nose at 50 KIAS***
5. Climb Speed - - ***65 -67 KIAS***

Important Airspeeds:

1. Best Angle of Climb - - ***Vx = 54 KIAS***
2. Best Rate of Climb - - ***Vy = 67 KIAS***
3. Cruise Climb - - ***70 - 80 KIAS***
4. Normal Approach - - ***Full Flaps = 60 KIAS***
5. No Flap Approach - - ***65 KIAS***
6. Best Glide - - ***60 KIAS***

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Pre-Landing Checklist:

1. Seats, Belts, Shoulder Harnesses - - ***Adjust & Lock***
2. Mixture - - ***Rich (in)***
3. Carburetor Heat - - ***On (out)***
4. Landing Light - - ***On***
5. Flaps - - ***As Desired***
6. Approach Airspeeds - -
   60 - 70 KIAS Flaps UP
   55 - 65 KIAS Flaps DOWN

Go Around / Balked Landing:

1. Throttle - - ***Full Open (in)***
2. Carburetor Heat - - ***Cold (in)***
3. Wing Flaps - - ***Retract to 20 Degrees***
4. Airspeed - - ***55 KIAS***
5. Wing Flaps - - ***Retract Slowly to Zero Degrees***
6. Climb Speed - - ***Best Rate Vy = 67 KIAS***

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After Landing:

1. Wing Flaps - - ***Up***
2. Carburetor Heat - - ***Cold (in)***
3. Transponder - - ***Standby***
4. Landing Light - - ***Off***
5. Elevator Trim - - ***Takeoff***
6. Mixture - - ***Lean one inch***

Securing Airplane:

1. Radio, Electrical Equipment - - ***Off***
2. Magneto Check - - ***1000 rpm***
3. Throttle - - ***1200 rpm***
4. Mixture - - ***Idle Cutoff (Full out)***
5. Ignition Switch - - ***Off***
6. Master Switch - - ***Off***
7. Control Lock - - ***Install (yoke)***
8. Lock Doors, Covers / Flags, Tie Down, Chock Wheels - -

Prepare for next SAFE flight!

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Emergency Checklists:

Airspeeds For Emergency Operations:

Engine Failure After Takeoff - -	***60 KIAS***
Maneuvering Speed :	
1670 Lbs. - -	***104 KIAS***
1500 Lbs. - -	***98 KIAS***
1350 Lbs. - -	***93 KIAS***
Maximum Glide - -	***60 KIAS***
Precautionary Landing w / Power - -	***55 KIAS***
Landing w / out Engine Power - -	
Wing Flaps UP - -	***65 KIAS***
Wing Flaps DOWN - -	***60 KIAS***

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Emergency Procedures:

Engine Failure During Takoff Run

1. Throttle - - ***Idle***
2. Brakes - - ***Apply***
3. Wing Flaps - - ***Retract***
4. Mixture - - ***Idle Cut-Off***
5. Ignition Switch - - ***Off***
6. Master Switch - - ***Off***

Engine Failure Immediately After Takeoff

1. Airspeed - - ***60 KIAS***
2. Mixture - - ***Idle Cut-Off***
3. Fuel Shutoff Valve - - ***Off***
4. Ignition Switch - - ***Off***
5. Wing Flaps - - ***As Required***
6. Master Switch - - ***Off***

Engine Failure During Flight

1. Airspeed - - ***60 KIAS***
2. Carburetor Heat - - ***On (out)***
3. Primer - - ***In and Locked***
4. Fuel Shutoff Valve - - ***On***
5. Mixture - - ***Rich (in)***
6. Ignition Switch - - ***Both (or START if Propeller is stopped)***

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Emergency Procedures:

Emergency Landing w/out Engine Power

1. Airspeed - - ***65 KIAS (flaps UP)***
   60 KIAS (flaps DOWN)
2. Mixture - - ***Idle Cut-Off***
3. Fuel Shutoff Valve - - ***Off***
4. Ignition Switch - - ***Off***
5. Wing Flaps - - ***As Required***
6. Master Switch - - ***Off***
7. Doors - - ***Unlatch Prior to Touchdown***
8. Touchdown - - ***Slightly Tail Low***
9. Brakes - - ***Apply Heavily***

Precautionary Landing with Engine Power

1. Airspeed - - ***60 KIAS***
2. Wing Flaps - - ***20 Degrees***
3. Fly Over - - ***Field/ Note Terrain Obstructions***
4. Radio / Electrical Switches - - ***Off***
5. Wing Flaps - - ***30 Degrees on Final Approach***
6. Airspeed - - ***55 KIAS***
7. Master Switch - - ***Off***
8. Doors - - ***Unlatch Prior to Touchdown***
9. Touchdown - - ***Slightly Tail Low***
10. Ignition Switch - - ***Off***
11. Brakes - - ***Apply Heavily***

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