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ABSTRACT

This curriculum guide is an accompanying publication for the textbook entitled "Air Navigation" in the Aerospace Education II series. The guide provides guidelines for teachers using the textbook in terms of objectives, behavioral objectives, suggested outline, orientation, suggested key points, suggestions for teaching, instructional aids, projects, and further reading for each chapter. A blank sheet is attached after each chapter for recording teacher ideas. Page references are given corresponding to the textbook. (PS)

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AE-II

INSTRUCTIONAL UNIT III

AIR NAVIGATION

PREPARED UNDER

THE DIRECTION OF

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INSTRUCTIONAL UNIT III

AIR NAVIGATION

INSTRUCTIONAL UNIT OBJECTIVES: At the completion of this unit of instruction each student should:

a. Know the four elements of Air Navigation and be able to apply them.

b. Be able to use maps and charts for pilotage navigation.

c. Be familiar with the various types of projections and aeronautical symbols used in air navigation.

d. Know the basic navigation instruments and be familiar with how to use them.

e. Understand the determination and use of Dead Reckoning Techniques.

f. Be familiar with the basic principles and use of aids to navigation.

g. Be able to measure a course with the Plotter.

h. Be able to solve navigation and math problems with the Dead Reckoning Computer.

PHASES IN INSTRUCTIONAL UNIT III:

PHASE I - FROM HERE TO THERE

This phase is a simple introduction to the four elements of navigation: time, distance, position, and direction. After the terms are defined, they are applied to a hypothetical automobile trip. Also introduced is the use of the map.

1. PHASE I OBJECTIVES: At the completion of this phase of instruction each student should--

   a. Know the basic elements of navigation.

   b. Understand how the basic elements of navigation are applied.

   c. Be familiar with the parts of a map.

   d. Know how to use a map for highway navigation.

2. BEHAVIORAL OBJECTIVES: At the completion of this phase of instruction each student should be able to--

   a. Apply the basic elements of navigation in planning a road trip.

   b. Locate and use the map elements necessary for a road trip.

   c. Identify the different features given in a map Legend.

3. SUGGESTED OUTLINE:

   a. The basic elements of navigation as applied to a road trip

      (1) Position

      (2) Direction

      (3) Distance

      (4) Time

   b. Map Elements

      (1) Legend

      (2). Relief Features

      (3) Cultural Features

      (4) Hydrographic Features

4. ORIENTATION:

a. This first phase is meant primarily for those students who have had very little background working with maps. It is not intended to be an in-depth study. The latter section, dealing with features portrayed on a map, initiates the student into more detailed study. This phase begins with the planning of a hypothetical road trip. It breaks the trip down into the four elements of navigation: position, direction, distance, and time. After defining the four elements, the phase ends by getting the student to take a closer look at the map and identify the features portrayed.

5. SUGGESTED KEY POINTS:

a. Before attempting to talk about Air Navigation the student must examine the fundamentals of navigation in an environment he understands. Navigation takes place every day of our life. When we leave home and proceed to school, or the bowling alley, or even to a girl's house, we navigate. This navigation takes place whether we drive, walk, or ride a bicycle. A further example of navigation is when directions are given to someone. Many times we have directed someone by saying, "Go three blocks south on Main, turn left, and go to the second traffic light, that's Hall Street." Whether we are conscious of it or not, in every case we have applied the four elements of navigation: Position, starting from our house; Direction, which way do we turn out of our driveway; Distance, how far is it to Mary's house; and, Time, how long will it take me. After traveling over the same route many times most of these elements are assimilated so that we don't even think of them. This is not so different from a Navigator who has flown the same route time and again. In Vietnam, the country was so small that Pilots/Navigators became familiar with the countryside quickly and rarely had to pull out their maps after the first few missions.

*** (AFM 51-40, Vol 1) p 2-1

b. A chart Legend is the key which explains the meaning of the relief, culture, hydrography, and vegetation features. Legend means "to be read." The Legend really encompasses everything on the chart that helps a person read it. All this information included in the Legend is extremely important at different times and therefore it is imperative that a Navigator on land, or in the air, understands how to use it.

*** (V-9177) p 61

* (AFM 51-40, Vol 1) pp 3-24

c. Relief or Hypsography features are the physical features in relation to elevation. When relief is shown by contour lines, the interval between these lines depends upon the

** (AFM 51-40, V.1) pp 3-25 thru 3-27

scale of the map and the terrain depicted. Spot elevations can be above any established datum plain but usually sea level is used. Shading is applied to the "southeastern" side of elevated terrain and "the" northwestern side of depressions. Shading gives a three-dimensional effect.

d. Cultural features are governed by (1) the scale of the chart, (2) the use of the chart, and (3) the geographical area covered. The true representative size and shape of larger cities and towns is usually shown. The text points out however that standardized symbols are used to represent smaller population centers.

e. The Army makes extensive use of Vegetation Features. They take special care in mapping woodland cover, however, vegetation in many areas is subject to rapid growth or elimination by cutting or burning. They warn that a user should determine the last date of information of the map and gauge the reliability of the woodland information accordingly. Only perennial types of growth are mapped. Isolated and low scattered growths are usually omitted. Small clumps of growths are usually omitted except where they serve as landmarks in areas of little woodland cover. Small clearings are usually omitted. Depending upon the area, growth having as little as 20 to 35 percent canopy cover is symbolized as continuous.

6. SUGGESTIONS FOR TEACHING:

a. Suggested time: 1-1-2 (Translation--if you teach two academic periods per week we recommend you devote one hour to this subject. If you teach three periods per week the recommendation is still that you limit the coverage to one period. If you teach four academic hours per week you could devote two periods to the subject. These "Suggested times" are just that--recommendations. Adjust the emphasis according to interest and talent--both yours and the students'.)

b. Make this phase a fun part of the course. You don't even need to use the hypothetical trip from the text. Go get a bunch of maps of your local area and have the students plan a trip like ours. It will be more fun to talk about position, direction, distance, and time in terms of points that are familiar.

c. If your students are not familiar with maps, spend a little time making the student comfortable with the map. If he leaves this chapter with little understanding, he has little chance with the rest of the text.

d. Do not lecture. This is a hands-on phase. Have maps handy for use. Encourage the students to look for things on maps. Make up teams and have them identify items you describe on the map. For example, "Identify the hydrographic feature 26 miles east of ______ town." There are many more examples. A whole class can be spent on identifying features on a map.

e. Have Fun!!! Make Navigation Fun!!! Think about foregoing a test even.

f. A good transition into the next chapter is to compare auto or Army ground maps with air charts.

7. INSTRUCTIONAL AIDS:

a. Maps - you can get some free at your local gas station. Contact your area oil dealer representative to get road maps in bulk. They are usually glad to give them. Most states prepare a map of just their state. Contact the State Visitor's Bureau or Chamber of Commerce for these. Get some Army land maps of your area. Your nearest Army or Army National Guard unit should have plenty. AULC has some.

b. Air Force Films:

TF 1-4854 Basic Map Reading - Part I - Topographic Symbols, 18 min, B&W, 1953.

TF 6348A ________ - Part I - Map Symbols, 20 min, color, 1968.

TF 6348B ________ - Part II - Grid, Distance and Elevation, 29 min, color, 1968.

TF 6348C ________ - Part III - Direction, Orientation and Location Without a Compass, 30 min, color, 1968.

TF 6348D ________ - Part IV - Direction, Orientation and Location With a Compass, 30 min, color, 1968.

TF 6348E ________ - Part V - Photos and Photomaps, 31 min, B&W, 1966.

c. Army Films:

Army TF 5-2409 Contour Lines and Intervals
Army TF 5-2410 Direction
Army TF 5-2411 Elevation
Army TF 5-2413 Location
Army TF 5-2416 Scale and Distance

8. PROJECTS:

a. See suggestions in the text, titled "Things to Do."

b. The navigation rally is a great teaching tool, but do not let it turn into a race.

c. Plan and conduct a map reading/navigation exercise on a hike through the local area. Have it a competition much like a car rally, only walking.

9. FURTHER READING:

a. Army Field Manuals (FM)

FM 21-26-1 Map Reading
FM 21=31 Topographic Symbols

NOTE: This phase has some innovations for AFJROTC. Use the next page to let us know what you think about them.

AIR NAVIGATION

PHASE I

IDEAS FOR IMPROVEMENT OF THE TEXTBOOK
AND/OR INSTRUCTOR'S GUIDE AND TEACHING
TECHNIQUES MOST EFFECTIVE FOR THIS PHASE.
TO BE COMPILED AT END OF TEXT AND SENT TO JRC

PHASE II - FROM HERE TO THERE IN THE AIR

In this phase we start to apply navigation concepts to flying. We parallel Phase I by using a hypothetical flight to show how the navigation elements are applied. As we proceed through the planning process a close look is taken at different types of charts and the parts of the charts. The four elements of navigation are applied in pre-flight planning. Phase II goes further than the first phase by applying the pre-flight planning to the flight. The phase ends by giving advice on what to do in case a person becomes lost.

1. PHASE II OBJECTIVES: At the completion of this phase of instruction each sutdent should--

   a. Be familiar with the different charts used for landmark flying.

   b. Know how scale affects charts.

   c. Understand the parts of aeronautical charts and how to use them.

   d. Be familiar with aeronautical symbols and their meaning.

   e. Understand how to pre-flight for a flight to be navigated by pilotage.

   f. Be familiar with the aids available to help pre-flight for pilotage.

   g. Be familiar with in-flight pilotage techniques.

   h. Be familiar with procedures to be followed if they should become lost in flight.

2. BEHAVIORAL OBJECTIVES: At the completion of this phase of instruction each student should be able to--

   a. Select the proper chart for landmark flying according to the type aircraft and altitude to be flown.

   b. Explain what scale is and how it is derived.

   c. Use the different parts of a chart.

   d. Identify symbols on a navigation chart.

e. Prepare a complete pre-flight for a 150 nm or more flight to be navigated by pilotage.

f. Obtain needed information from the AIM, NOTAMS, and PIREPS.

g. Navigate a short navigation leg by pilotage. (Note this can be demonstrated by a ground mission with instructor inputs.)

h. Recite procedures to be followed if lost inflight under various conditions.

3. SUGGESTED OUTLINE:

a. Air Navigation Charts

(1) Scale

(a) JN chart

(b) ONC chart

(c) Sectional chart

(2) Parts of Charts

(a) Title information

(b) Relief features

(c) Aeronautical symbols

(d) Prohibited, restricted, warning, and alert areas

b. Pilotage Flight Planning

(1) AIM

(a) NOTAMS

(2) PIREPS

(3) VFR Pilot Exam-O-Grams

(4) Pre-flight

c. Navigating by Pilotage

d. Procedures to be followed if lost

4. ORIENTATION:

a. Pilotage is the easiest method of navigation to learn. However, it is not necessarily the easiest to do. The student beginning this phase of instruction is probably still at a very low level of navigational ability. A more deliberate pace should be taken. Upon completion the student should be well-grounded in the fundamentals of pilotage. The student should also be impressed with the importance of planning.

5. SUGGESTED KEY POINTS:

*** (V-9171) pp 38-43

a. Aeronautical charts are a necessary part of every flight. Even though a pilot may become very familiar with his intended route of flight there might always be the day when weather or some malfunction may dictate a change in the route. Charts for along the route as well as adjacent charts should be carried for every flight. There are two basic types of charts being used by pilots today:

*** (V-9161) pp 9-4 thru 9-24

(1) Charts that show all significant features for air navigation and aeronautical information.

** (V-9015) pp 285-288

(2) Charts that show radio navigation facilities and little or no relief, cultural, and hydrographic features.

* (V-9013) pp 571-572

The beginning pilot generally flies light aircraft "low and slow." To navigate he needs the first type of chart. Pilots of higher performance aircraft usually fly at high altitudes where they can do very little pilotage. These pilots are interested in radio and aeronautical information.

*** (V-9171) pp 84-97

*** (V-9161) pp 7-1 thru 7-42

* (V-9162) pp 138-141

(V-9013) pp 637-639

* (V-9156) pp 384-425, 467-469, 470-474

b. Probably some of the most important time spent in flying is before the pilot ever gets to the aircraft. Pre-flight planning is necessary even on short flights over very familiar routes. Arriving at a destination and finding the runway closed for repairs is at the least embarrassing, and it can be extremely dangerous. Full use of the information contained in AIM is a necessity. The AIM is easy to use. After determining from the first page of any part of AIM where the information he needs is located the pilot/navigator should examine the table of contents or index for that part. For instance, suppose he wants to check the status of the destination airport. Part 2 is the Airport Directory. It is arranged alphabetically under the Part 2 section "Airport Directory." After turning to the individual airport listing, the "Airport Directory Legend" can be referred to so that the desired information can be found. In addition, the pilot/navigator should check the latest published information in Part 3A - "Notices to Airmen." The AIM is packed with valuable information. Every flier needs to be familiar with the information this document can give.

c. For every flight the weather should be checked. If the flight is going to be over one hour it is required that weather charts and PIREPs be consulted. Weather briefings over the phone are allowed. The best weather briefing is in person however. Being able to see the charts yourself helps in understanding. If it is impossible to get an in-person weather briefing the next best thing is to get a phone briefing. Telephone numbers of Flight Service Stations (FSS) and National Weather Service Offices are located in Part 2 of AIM. The briefing should include:

*** (V-9161) pp 9-39 thru 9-42

(1) Destination weather

** (V-9177) pp 3-5, 85-86

(2) Weather enroute

* (V-9065) pp 118-119

(3) Alternate route and destination weather

** (V-9162) pp 152-163

(4) Precipitation, sky cover, and visibility for all points along the route and alternate route

* (V-9013) pp 502-505

** (V-9002) pp 370-374

(5) Frontal activity

** (V-9167) pp 49-64

(6) Winds at planned flight altitude

** (V-9156) pp 254-281

(7) NOTAMs

d. After drawing the course on the chart and picking out the route to fly a log should be developed. This log should contain all the data necessary for the trip. The checkpoints along the route can be entered in the log so that they can be referred to in flight. Right here the instructor may want to rearrange the student's reading assignment. It would be quite appropriate to skip to Chapters 3 and 5 and study headings. The FAA has reported that a review of fatal accident statistics for a year shows that as a "cause factor," inadequate flight planning was second only to "failure to maintain airspeed resulting in a stall."

** (V-9161) pp 9-34 to 9-37
*** (V-9177) pp 86-95
** (V-9162) pp 175-179

e. The statement "NO FLIGHT PLAN FILED" which appears in many accident reports and accounts of extensive search operations for missing aircraft, indicates a degree of thoughtlessness on the part of the pilot for the safety of his flight. Two examples of recent accidents point this up:

** (V-9162) pp 179-180
* (V-9156) pp 409-410
* (V-9177) pp 85-86

(1) "Businessman-pilot flying daughter home from college crash lands in sparsely populated area resulting in injury to father and daughter. Rescue effected within three hours of ETA near flight plan course filed with FAA.

(2) Family of five forced down by snow storm while on flight to winter resort. No flight plan filed with FAA and five days later family reported missing by relatives. Search parties, after covering extensive area, find bodies with no injuries -- expiration attributed to exposure.

*** (V-9162) pp 181-184
** (V-9177) pp 63-64

f. There are some good practices to establish while navigating by pilotage. Hold the map so the course line on the map parallels the course you are flying. Everything will appear in its proper place. Unfortunately the names of towns and other written data will sometimes be hard to read but this is better than getting the relative position of checkpoints confused. When a checkpoint is found and the aircraft is off course a correction back to course should be done immediately. Check groundspeed frequently. Get head and eyeballs out of the cockpit. Keep up with checkpoints, listen to the weather broadcasts for the area. Call in position, time, and altitude to FSS periodically. In turn, the FSS will give the local altimeter setting. Don't forget to close the flight plan.

*** (V-9162) pp 183-184
** (V-9177) pp 97-99

g. No pilot or navigator ever gets lost, only "temporarily disoriented." Okay, now what happens when the pilot gets lo--, uh, disoriented. If he has a radio there are over 20,000 individuals and aids that are standing by to help. If he panics then nobody is going to help very much. The FAA in Exam-O-Grams No. 18 and No. 19 gives some outstanding advice. They list the "Four "C" Procedure":

(1) CONFESS - Don't wait too long to ask for help.

(2) COMMUNICATE - "If in doubt, shout." Any radio facility can be contacted on the emergency frequency (121.5 MHz). Give whoever answers the pertinent information of the predicament and they will find help.

(3) CLIMB, if possible. Altitude improves VHF capability and increases likelihood of Radar and D/F identification.

(4) COMPLY with the instructions of the ground contact.

6. SUGGESTIONS FOR TEACHING:

a. Suggested time: 3-4-5 (Translation--if you teach two academic periods per week we recommend you devote three hours to this subject. If you teach three periods per week you could devote four periods. If you teach four academic hours per week you could devote five periods to the subject. These "Suggested times" are just that--recommendations. Adjust the emphasis according to interest and talent--both yours and the students'.)

b. If you have no experience in navigation learn with the students and have a ball!! This phase, like the first, should also be fun. If you are uncomfortable in this area don't be afraid to bring in your local airport ground school instructor or someone from CAP.

c. Emphasis should be placed on how aeronautical chart symbols differ from those on a road map. This subject is a natural for student-centered activity. You should have received enough obsolete sectionals from JRC so that each student can plan a mission.

d. A first exercise that can be done is merely map reading (recognition of symbols). When the students have become familiar with these symbols let them plan their own flight. You may want them to break-up into groups and plan the flight rather than do it individually. Each group can then also prepare an FAA flight plan (blank forms probably can be obtained from your nearest airport or FAA facility). A handout with the origin, destination, aircraft cruising speed, etc. would give the student sufficient information to plan a simulated flight for this exercise.

e. If possible let the students fly a flight they have planned. Plan a four leg navigation route and have each student navigate a leg. If you use civilian aircraft, be sure your school approves and it is in accordance with AFROTCM 50-3. A good system is to establish navigation legs for a local military orientation flight.

f. The flight in the text is oversimplified in many aspects. For instance, the figuring of headings is ignored here. You might detour prior to this phase to Appendices A and B so that you can get more detailed in this phase.

g. You might also want to skip ahead to the Compass Section in Chapter 5 and discuss the figuring of various headings.

7. INSTRUCTIONAL AIDS:

a. Try to obtain Sectionals of your local area. Your support base might supply them.

b. FAA Flight Plan Form - if sufficient copies are not available, they can be easily reproduced on a copy machine.

c. Navigation Plotters are nice but for a simple mission like this one a ruler is sufficient.

d. If you decide to skip ahead to Chapter 5 to discuss headings you might want to obtain some Flight Logs to figure the headings, airspeeds, and fuel. Simple logs can be obtained at most airports. Air Force Logs might be a little complicated for this phase of instruction.

e. Air Force Films:

SFP 1669. Flight Information Publications -- FLIPS, 20 min, color, 1968.

TF 1-3460. Aerial Navigation -- Map Reading, 21 min, B&W, 1945.

TF 1-4990. Primary Pilot Navigation -- A Step in the Right Direction, 27 min, color, 1955.

TF 5732. Low Level Air Navigation Familiarization, 22 min, color, 1960.

f. FAA Films:

FA-902. Basic Radio Procedures for Pilots, 30 min, color, 1970.

FA-209. One Eye on the Instruments, 16 min, 1962.

FA-612. Path to Safety, 20 min, 1967.

FA-129. To Save A Life, 13 min, 1961.

FA-04-71. Weather to Fly, 27 min, 1971.

g. Overhead Transparencies:

V-1013 Weather Map

V-1014A Teletypewriter Weather Reports

V-1016 FAA Flight Plan

V-2005 Weather (Book of Transparencies)

8. PROJECTS: Some good ones have already been mentioned; others are listed in the text under "Things To Do."

9. FURTHER READING:

a. See Suggestions for Further Readings in Text.

b. Federal Aviation Regulations (FARs).

NOTE: This phase has some innovations for AFJROTC. Use the next page to let us know what you think about them.

AIR NAVIGATION

PHASE II

IDEAS FOR IMPROVEMENT OF THE TEXTBOOK
AND/OR INSTRUCTOR'S GUIDE AND TEACHING
TECHNIQUES MOST EFFECTIVE FOR THIS PHASE.
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PHASE III - NAVIGATION ELEMENTS

This phase begins our in-depth study of Navigation. Continuing our theme of the four navigation elements, we study each attempting to bring the students up to the "understand" level for each. A discussion of position is preceded by a look at the Earth and some simple spherical concepts. Distance, Direction, and Time are studied next.

1. PHASE I OBJECTIVES: At the completion of this phase of instruction each student should--

   a. Understand how the earth's size and shape are divided for measurement and location.

   b. Know how to determine a position through the use of latitude and longitude.

   c. Understand the measurements of distance.

   d. Understand the measurements of direction.

   e. Understand how time is determined and its use in Navigation.

2. BEHAVIORAL OBJECTIVES: At the completion of this phase of instruction, each student should be able to:

   a. Describe the difference between great circles and small circles on earth.

   b. Plot positions on a globe or chart through the use of latitude and longitude.

   c. Convert the measures of distance from one to another, i.e., nm to km, statute miles to nm, etc.

   d. Describe direction to be traveled in terms of degrees from the compass rose.

   e. Differentiate between course, heading, and track.

   f. Describe the difference between rhumb line and great circle routes.

   g. Apply GMT and zone time concepts.

3. SUGGESTED OUTLINE:

a. Earth's Size and Shape

(1) Great Circles

(2) Small Circles

b. Position

(1) Coordinates

(a) Latitude

(b) Longitude

(2) Finding the Place

(a) Degrees, minutes, and seconds

c. Distance

(1) Nautical Mile

(2) Statute Mile

(3) Kilometer

(4) Knots

d. Direction

(1) The Compass Rose

(2) Course, Heading, and Track

(3) Great Circle and Rhumb Line Routes

e. Time

(1) Zone Time

(2) GMT

4. ORIENTATION:

a. Things are starting to get just a little deep. This phase begins to really get the student to understand the concepts that go together to make Phases I and II fun. The discussion of the Earth's size and shape, especially the part about rhumb lines and great-circles, is just an inkling of what is to come in Phase IV. Latitude and longitude are discussed in terms of position and a lot of practice is needed in this area. The kinds of distance are studied followed by direction and time.

5. SUGGESTED KEY POINTS:

*** (AFM 51-40, V. 1) pp 2-1 thru 2-5
** (V-9177) pp 8-10

a. A degree of latitude at any point on the earth is the same length, 60 nm. A degree of longitude, which is measured east and west along a parallel varies in length depending on latitude. At the equator a degree of longitude equals 60 nm, at 60° latitude it equals about 30 nm, and at the poles a degree of longitude equals zero nm.

*** (AFM 51-40, V. 1) pp 3-28 thru 3-38

b. Using latitude and longitude is only one method of referencing a point on the earth. The spherical coordinate system is difficult to use in many cases because its units of degrees, minutes, and seconds are not comparable to the normal units of surface measurement. The Military Grid Reference System was designed to use with the standard unit of measurement, the meter. Using the Universal Transverse Mercator (UTM) and the Universal Polar Stereographic (UPS) chart projections, the world is divided into large, regularly shaped geographic areas. These are identified by a Grid Zone Designation such as 43P. These areas are subdivided into 100,000 meter squares and are identified by adding a two-letter designation to the Grid Zone Designation, e. g., 43PRS. Within the 100,000 meter square a point can be located by the use of numbers. For instance, a 100 meter area can be identified as 43PRS364397. One-half the numbers following the letters identify the east component, the other half the north component of the area. In our example we would locate the 100,000 meter block 43PRS. We would then take the next three numbers (364), since there are six, and find the east component. We would then take the last three numbers (397) and move north on the 364 line locating the 100 meter square. By this method we can locate a 1 meter square, if necessary. For instance, 43PRS3641239712 would locate a 1 meter square. Normally all elements of a grid reference are not used. Most of the time you know which 100,000 meter square you are working in; therefore, only the last numbers are used. Remember, start at the bottom left hand corner and read right with the first half of the digits and up with the last half. Notice that the reference is written in a continuous group - no spaces, parentheses, dashes, or decimal points. This system is sometimes called UTM coordinates. There are other systems that may be of interest such as GEOREF.

c. The meter is one ten-millionth part of the arc of the meridian between the equator and a pole. The kilometer equals about 3,280.83 feet.

d. Time is a lot more complicated subject than its coverage in the text. Most of the concepts of time are necessary for celestial navigation. Apparent Solar Time, Mean Solar Time and conversions of these to GMT are things the average student will probably never use, however, it can be interesting. Time is measured in terms of the rotation of the earth and the resulting apparent motions of the celestial bodies. The sun as seen in the sky is called the true sun, or apparent sun. Apparent solar time is time based upon the movement of the sun as it appears in the sky. This was the original measurement of time when it was measured by a sundial.

*** (AFM 51-40, V. 1) pp 12-1 thru 12-5

A mean day is an artificial unit of constant length. It is based on the average of all apparent solar days over a period of years. Time based on the mean sun is called Mean Solar Time and is nearly equal to the average apparent solar time. Since the Air Almanac lists where the celestial bodies are in terms of mean solar time, it is the time of primary interest to the navigator using celestial navigation. The difference in length between the apparent day (based upon the "true" sun) and the mean day (based upon the "fictitious" sun) is never as much as a minute. The differences are cumulative, however, with the result that the imaginary mean sun precedes or follows the apparent sun by approximately a quarter of an hour at certain times during the year. Greenwich Mean Time (GMT) and Local Mean Time are based on mean solar time.

e. If a person were to travel west from Greenwich around the world, setting his watch back an hour for each time zone, he would have set his watch back a total of 24 hours when he arrived back at Greenwich. The date of the traveler would be one day behind that of Greenwich. On the other hand, traveling eastward, he would advance his watch a total of 24 hours and would gain a day in comparison with Greenwich. To compensate for this it is necessary to add a day somewhere if going around the world to the west and to subtract a day if going around to the east. The 180° meridian was selected arbitrarily as the international date line; where a day is gained or lost. The date line follows the meridian except where it makes wide detours to avoid Eastern Siberia, the western Aleutian Islands, and several groups of islands in the South Pacific.

6. SUGGESTIONS FOR TEACHING:

a. Once again do not get locked in by a certain time frame for this phase. You may want to expand each sub-part of this phase. On the other hand, you might not want to teach this phase as an entity at all. For instance, Position with its look at the earth and its grid system could very easily go with Phase IV. Chapter II of the text flies a mission with no mention of headings. This may be so incongruous to some instructors as to be impossible. Go ahead and include the direction section of this phase with your study of Phase II.

b. Suggested time: 2-3-4 (Translation--if you teach two academic periods per week we recommend you devote two hours to this subject. If you teach three periods per week you could devote three periods. If you teach four academic hours per week you could devote four periods to the subject. These "Suggested times" are just that--recommendations. Adjust the emphasis according to interest and talent--both yours and the students'.)

c. This phase will probably take some lecture and demonstration to get across points such as rhumb lines and great circles. The majority of the phase still should be student centered activity however. Plotting coordinates, figuring directions, converting distances and speeds all can be fun and challenging activities. Make them so!!

d. The Army's UTM Grid System is not mentioned in the text. Here is a place for you to shine. Study up on it a little, get some local Army maps (your local Army Guard Unit will have them) and show how the system works. For those who are inclined to the outdoors and lucky enough to have some kind of an area to do so, you might set up a ground navigation competition. This type of thing is becoming a recognized sport and is going to be entered as an offical Olympic competition.

e. This might be the place to slip back to the Appendices and study the Dead Reckoning Computer and Plotter. It would certainly enhance the sections on Distance and Direction.

7. INSTRUCTIONAL AIDS:

a. Air Force Films

TF 6348B Basic Map Reading - Part II - Grid, Distance, and Elevation, 29 min, color, 1968.

TF 6348C ____________ - Part III - Direction, Orientation and Location Without a Compass, 30 min, color, 1968.

b. Army Films

Army TF 5-2410 Direction

Army TF 5-2416 Scale and Distance

c. Try to obtain Army maps of your local area from the nearest Army or Army National Guard Unit.

8. PROJECTS:

a. See suggestions in the text for "Things to Do."

b. Consider the suggestion for a ground navigation problem in b. d. above. Get a local Army unit to brief you on how it is done and do it. Maybe you can beat the nearest Army JROTC Unit in a navigation contest.

c. Have a group of your cadets teach Aerial Navigation to nearby Army and Navy JROTC Units and have them teach your cadets land and sea navigation.

d. The following is a fun test that makes the point that many people perceive a two-dimensional world:

THE WORLD IS FLAT

Geography "Test"

To prepare for this examination, it is necessary that a visual image of the world is formed in the mind's eye of the examinee. This visualization of the world should be the most comfortable and reliable reference the examinee can call to mind. Once the world image is established the examination may begin.

1. Traveling the shortest route possible, the direction of travel between Rio de Janerio and Darwin, Australia, is ______________ (Major or Minor compass point).

2. Let's compare the size or land area of Greenland with the land area (size in sq. miles) of South America. Greenland is _____ larger, _____ smaller, _____ approximately the same size of South America.

3. Traveling due south from New Orleans, Louisiana, what part of South America (not Central America) would you touch first?

4. Traveling the shortest possible route, the general direction of travel between Miami, Florida, and the Panama Canal is ____________. (A Major or Minor compass point).

5. Traveling the shortest possible route, the direction of travel between New York City and Chungking, China, is _________. (Major or Minor compass point).

6. The general direction of flow of the St. Lawrence River is _________.

7. Traveling through the Panama Canal, from the Atlantic side to the Pacific side, you would travel _________ (Major or Minor compass point) as a general direction?

8. Reno, Nevada, is north and _________ of Los Angeles, California.

9. Caracas, Venezuela, lies closer to Miami, Florida, than does Minneapolis, Minnesota. _____ True _____ False.

10. Traveling the shortest possible route, which city, London or New York, lies closest to Tokyo, Japan?

THE WORLD IS FLAT

Answer Key to Geography "Test".

1. South to the Pole, North to Darwin.
2. Smaller, Greenland is 1/9th the size of South America.
3. You wouldn't. You'd be out in the Pacific. South America is actually ESE America.
4. East of Due South. You're farther east when you reach the Panama Canal than when you leave Miami.
5. North to the Pole, South to Chungking.
6. Northeast.
7. Southeast. You're approximately 12 miles east of where you entered the Canal on the Atlantic or Gulf of Mexico side.
8. West.
9. True.
10. London. By more than 900 miles.

9. FURTHER READING:

Army Field Manual FM 21-26-1, Map Reading.

Civil Air Patrol, Navigation and the Weather, Maxwell AFB, Alabama, Headquarters Civil Air Patrol.

NOTE: Please help us improve this text. Jot down strengths, weaknesses, and suggestions for this phase. Upon completion of the text forward them to JRC.

AIR NAVIGATION

PHASE III

IDEAS FOR IMPROVEMENT OF THE TEXTBOOK
AND/OR INSTRUCTOR'S GUIDE AND TEACHING
TECHNIQUES MOST EFFECTIVE FOR THIS PHASE.
TO BE COMPILED AT END OF TEXT AND SENT TO JRC

PHASE IV - "IF IT WERE ONLY FLAT"

This phase introduces the student to the subject of projecting the earth and its features onto charts that can be used for air navigation. The problem of projection and the errors it creates is followed by a discussion of different projections and their use and limitations in air navigation. The title of this phase is a lament that most of us cry after having studied this areas. However, it is important for students to understand this information so that they don't become confused when they attempt to measure courses and distances.

1. PHASE IV OBJECTIVES: At the completion of this phase of instruction each student should--

   a. Be familiar with the problems involved in making projections.

   b. Understand how projections are classified.

   c. Understand the differences between azimuthal, cylindrical, and conic projections along with the difference between gnomonic and stereographic projections.

   d. Understand the uses of conformal, mercator, and gnomonic charts.

2. BEHAVIORAL OBJECTIVES: At the completion of this phase of instruction each student should be able to--

   a. Explain the difference between a developable and undevelopable surface.

   b. Describe three types of distortion caused by projection methods.

   c. Describe how projections are classified.

   d. Identify the characteristics and uses of gnomonic, polar, stereographic, mercator, and conformal charts.

   e. Describe the differences between azimuthal, cylindrical, and conic projections.

   f. Measure courses and directions correctly on different types of charts.

3. SUGGESTED OUTLINE:

   a. The Problem

(1) Undevelopable Surface

(2) Developable Surface

b. Distortion Caused by Projection

(1) Size Distortion

(2) Shape Distortion

(3) Direction Distortion

c. Projection Classification

(1) Type of Surface

(2) Point of Tangency

(3) Point of Projection

d. Projection Characteristics

(1) Ideal Chart

(2) Azimuthal Projections

(a) Gnomonic

(b) Stereographic

(3) Cylindrical Projections

(a) Mercator

(4) Conical Projections

(a) Parallel of Tangency

(b) Secant Cone

e. Lambert Conformal Chart

f. Measuring Distance and Direction on Different Projections.

4. ORIENTATION:

a. This phase of instruction, probably the hardest in the unit, introduces the student to what goes into making a flat chart from a spherical earth. After this phase the student should understand why some maps show a huge Greenland or a long thin Texas. For our specific purpose he should also know where to measure distance and direction on a particular chart. Although it is not a big problem for light aircraft fliers they should be aware of the limitations of charts used for navigation.

5. SUGGESTED KEY POINTS:

a. John V. Sorenson, of the CAP, writes in his monograph "The World is Flat and I can Prove It," "The History of Man is the History of Transportation." Most of that transportation, except for air transport, was guided by a series of maps based upon a cylindrical projection known as the Mercator World Map. J. Parker Van Zandt, famous American geographer, made some rather specific statements as a result of a study, The Geography of World Air Transport, he completed for the Brookings Institution in 1940. In this segment of the study he was talking about:

THE MERCATOR WORLD MAP

Most of us have a mental picture of a world that isn't so. Our ideas of the world are largely based on a map devised 375 years ago. Invented in 1569 by a Flemish geographer whose Latinized name was "Mercator," it was a wonderful map in its day and still is unsurpassed for certain purposes. (This chart was and is a document of the sea which served the mariner and seapower. JVS)

But used as a pictorial likeness of the earth we live on, the Mercator world map and other similar projections have done immense harm. Their grotesque distortions have colored our international thinking, fostered isolationism, and warped our outlook for generations.

Mercator wall maps have hung before us so long in classrooms, lecture halls, and offices that their untruths are in our very blood.

Any flat map of the entire world, no matter what the projection, involves great distortion.

Many ingenious suggestions have been made, but the fundamental dilemma remains: no continuous flat map can present a satisfactory facsimile of the surface of an entire sphere.

As much as half a world can be pictured reasonably well by several different projections. Beyond a hemisphere, however, the surface of the earth curves inward, while the map perforce continues to spread outward with the unavoidable result that some interruption becomes inevitable, while the distortions grow unrealistically large.

Hemispheres are what you make them. There has not been enough understanding on this important aspect of history and geography.

b. Because of the curvature of the earth, distortion becomes a serious problem in the mapping of large areas. Distortion cannot be entirely avoided, but it can be controlled and systematized to some extent in the drawing of a chart. If a chart is drawn for a particular purpose, it can be drawn in such a way as to minimize the type of distortion which is most detrimental to the purpose. Surfaces that can be spread out in a plane without stretching or tearing such as a cone or cylinder are called developable surfaces, and those like the sphere or spheroid that cannot be formed into a plane without distortion are called nondevelopable.

*** (AFM 51-40, V. 1) pp 3-2 to 3-3
* (V-9177) pp 13-14

c. The Lambert conformal conic projection and the Mercator cylindrical projection are primarily used in air navigation. Because of the exactness of these two types of charts, plotting, measuring, and map reading are made easier. The Mercator is the only projection that is conformal (leaving the size of the angle between corresponding curves unchanged; representing small areas in their true shape) and at the same time displays the rhumb line as a straight line. It is constructed by means of a mathematical transformation and cannot be obtained directly by graphical means. The distinguishing feature of the Mercator projection among cylindrical projections is that at any latitude the ratio of expansion of both meridians and parallels is the same, thus preserving the relationship existing on the earth. The chief use of the Lambert conformal conic projection is in mapping areas of small latitudinal width but great longitudinal extent. No projection can be both conformal and equal area, but by limiting latitudinal width, scale error is decreased to the extent that the projection gives very nearly an equal area representation in addition to the inherent quality of conformality.

*** (AFM 51-40, V. 1) pp 3-9 to 3-16
** (V-9013) pp 547-551
*** (V-9177) pp 17-31

d. An azimuthal projection is one in which points on the earth are transferred directly to a plane tangent to the earth. If the origin of the projecting rays (point of projection) is the center of the sphere, a gnomonic projection results. If it is located on the surface of the earth opposite the point of the tangent plane, the projection is a stereographic.

*** (AFM 51-40, V. 1) pp 3-4
** (V-9013) p 550
** (V-9177) pp 33-34

e. All gnomonic projections are direct perspective projections. The graticule is projected from a source at the center of the sphere onto a plane surface tangent at any given point. Since the plane of every great circle cuts through the center

*** (AFM 51-40 V. 1) pp 3-4

* (V-9065) pp 143-144

** (V-9177) pp 31-32

of the sphere, the point of projection is in the plane of every great circle. The arc of any great circle, being in the plane of the great circle, will intersect another plane surface in a straight line. This property then becomes the most important and useful characteristic of the gnomonic projection. Each and every great circle is represented by a straight line on the projection.

*** (V-9013) p 550

f. The stereographic projection is a perspective conformal projection of the sphere. It is one in which the point of projection is placed on the surface at the end of the earth's diameter opposite the point of tangency. A stereographic chart may be drawn to include an entire hemisphere, but for navigational purposes it does not generally extend beyond 15-20° from the pole.

6. SUGGESTIONS FOR TEACHING:

a. Suggested time: 3-4-4 (Translation--if you teach two academic periods per week we recommend you devote three hours to this subject. If you teach three periods per week you could devote four periods. If you teach four academic hours per week the recommendation is still that you limit the coverage to four periods. These "Suggested times" are just that--recommendations. Adjust the emphasis according to interest and talent--both yours and the students'.)

b. This is a tough phase. Unfortunately, the lecture/demonstration method will have to be used for the major portion of this phase. To help the teaching use training aids such as globes, tape measures, and examples of map projections.

c. Construct projects, using your students in small groups to measure and compare distances on different map projections. Select some students to give mini-reports on other projections not covered in this phase. Have them point out why the different projectjns are not used for air navigation.

d. Models can be used to demonstrate projection distortion. A good attention getter is to try to cut up a hollow tennis ball and try to flatten it out.

e. By the time you have reached this phase your students should be well motivated. Do not risk losing this motivation by dwelling on this phase too long. Get the major points across and move on. On the other hand you may find some of your students are very interested in this. Let them go off on their own or teach the others through reports and small group sessions.

7. INSTRUCTIONAL AIDS:

a. The Air University Library (AUL-C) at Maxwell Air Force Base, Alabama has many different projections. Let them know your needs.

b. Your school should have globes including transparent globes than can be used to demonstrate areas of this phase. If they don't have this equipment available, have them get some.

c. Air Force Films:

SFP 1238. Destination Where? 11 min. Color. 1965.

SFP 1670. Cartographic and Geodetic Products and Services. 20 min. Color. 1969.

SFP 1728. The Story of Navigation. 21 min. Color. 1968.

SFP 1867. Mission: Aerospace Cartography. 21 min. Color. 1971.

TF 5787. Performance Data Charts. 11 min. Color. 1966.

8. PROJECTS:

a. See suggestions in the text under "Things to Do."

9. FURTHER READING:

a. See "Suggestions for Further Readings" in the text.

NOTE: Please use the next page to let us know of suggested changes or modifications.

AIR NAVIGATION

PHASE IV

IDEAS FOR IMPROVEMENT OF THE TEXTBOOK
AND/OR INSTRUCTOR'S GUIDE AND TEACHING
TECHNIQUES MOST EFFECTIVE FOR THIS PHASE.
TO BE COMPILED AT END OF TEXT AND SENT TO JRC

PHASE V - NAVIGATION INSTRUMENTS

Various aircraft instruments have been developed to help pilot/navigators navigate their way across the world. This phase introduces the four basic instruments needed to help solve the four basic elements of navigation while inflight. Although other instruments greatly enhance navigation; the clock, airspeed indicator, altimeter, and compass are always essential for navigation. While learning about these instruments the student is also introduced to various airspeeds, altitudes, and headings.

1. PHASE V OBJECTIVES: At the completion of this phase of instruction each student should--

   a. Be familiar with the four basic instruments of navigation: the clock, airspeed indicator, magnetic compass, and altimeter.

   b. Understand the uses of the four basic navigation instruments and the information received from them.

   c. Understand the different types of airspeed and altitude.

   d. Understand the corrections necessary to attain different headings.

2. BEHAVIORAL OBJECTIVES: At the completion of this phase of instruction each student should be able to--

   a. Identify the primary uses of the four basic navigation instruments.

   b. Explain the relationship between the clock and fuel.

   c. Explain how the airspeed indicator works.

   d. Figure Indicated, Calibrated, and True airspeeds.

   e. Describe how the aneroid altimeter works.

   f. Read an altimeter.

   g. Explain how the five types of altitude differ.

   h. Explain how the magnetic compass works.

   i. Define variation.

   j. Figure True Heading and Compass Heading.

   k. Explain the advantages of the gyrocompass.

3. SUGGESTED OUTLINE:

a. Elements and Instruments of Navigation.

b. The Clock

(1) Fuel consumption

(2) Setting the clock

c. Airspeed Indicator

(1) Airspeed vs Groundspeed

(2) How it works

(a) pitot tube

(b) diaphragm

(c) linkage

(d) dial

(3) Types of Airspeed

(a) Indicated

(b) Calibrated

(c) True

d. Altimeter

(1) Aneroid Barometer

(2) Types of Altimeters

(a) How to use each

(3) Types of Altitude

(a) Absolute

(b) Indicated

(c) Pressure

(d) Density

(e) True

e. Compass

(1) magnetic compass

(2) Variation and Deviation

(3) Types of Heading

(a) Magnetic

(b) Compass

(c) True

(4) gyrocompass

4. ORIENTATION:

a. There is a fine line between what is and what is not a basic navigation instrument. The four mentioned in the book - clock, compass, airspeed and altimeter - are generally recognized as such. It is true that early aircraft had none of these instruments and still the pilots navigated by pilotage. In the modern era all aircraft are required to have these four instruments as well as specified engine instruments.

5. SUGGESTED KEY POINTS:

(V-9177) p 66

a. The clock or a personal watch is a must in today's air navigation. To assure accurate navigation a pilot must note his take off time, time proceeding on course, time over specified checkpoints, estimated and actual landing times and last, but most important, the elapsed time as it concerns fuel consumption. Many pilots have run out of gas because they depended solely on a malfunctioning fuel gauge. The safe pilot will always compare his fuel gauge readings with predetermined fuel consumption rates.

*** (AFM 51-40, V. 1) pp 4-24 to 4-30

** (V-9002) pp 222-225

*** (V-9013) pp 198-200

b. The airspeed indicator shows your speed through the air. Normally, the higher the flight altitude, the lower the air temperature and density, this will result in an instrument reading lower than the TAS. Calibrated airspeed is merely indicated airspeed corrected for installation error, i.e., position where the airspeed indicator's measuring devices are physically placed on the aircraft. A somewhat analogous situation would arise if an auto speedometer cable were connected to the wheel rather than the transmission, this could cause a difference or error in the speedometer.

c. The magnetic compass is the oldest and most reliable of all directional instruments. It functions much the same as the old Boy Scout compass, except that the aircraft compass rotates within a fluid. Just as the Boy Scout compass had to be held level in the hand to be accurate, only when the aircraft is flying straight and level in unaccelerated flight is its compass accurate. However, to make things easier a directional gyro was developed which eliminated many of these errors. However, the magnetic compass is still required to keep the gyro instruments oriented to the proper compass heading. Even in the largest most modern aircraft you will still find some facsimile of the old magnetic compass installed as an emergency backup for the new sophisticated compass systems which occasionally malfunction.

*** (AFM 51-40, V.1) pp 4-2 to 4-13
* (V-9002) pp 228-230
* (V-9013) pp 203, 207-208
* (V-9015) p 271
*** (V-9177) pp 75-80

d. The altimeter is primarily a safety instrument. If a pilot could always have 15 or 20 miles flight visibility, he would not need this instrument for navigation. However, when flying into areas of mountainous terrain with limited flight visibility, this is the only way a pilot can determine he is flying at a safe altitude. A night flight even in clear weather without an altimeter would be hazardous. It is almost impossible to visually determine the height above the ground at night. If it were a cloudless night with a full moon it would be possible but hazardous at best. The altimeter is merely an aneroid barometer with a dial calibrated in feet rather than inches of mercury. Therefore, to use it properly, it must be set to the proper field barometric pressure for each flight. If properly set, the altimeter will indicate height above sea level (indicated altitude). If the altimeter is set on the ground with the instrument indicating 0 feet altitude, then the instrument will indicate the height above the terrain in that particular area (absolute altitude). This is not desired when making an extended cross-country flight since terrain elevation and atmospheric pressure could be significantly different in an area several hundred miles away. Pressure altitude is the altitude above the standard datum and density altitude is corrected for non-standard temperature.

*** (AFM 51-40, V. 1) pp 4-14 to 4-20
* (V-9002) pp 225-227
* (V-9013) pp 200-202
* (V-9015) p 267
*** (V-9177) pp 71-75

6. SUGGESTIONS FOR TEACHING:

a. Suggested time: 2-3-4 (Translation--if you teach two academic periods per week we recommend you devote two hours to this subject. If you teach three periods per week you could devote three periods. If you teach four academic hours per week you could devote four periods to the subject. These "Suggested times" are just that--recommendations. Adjust the emphasis according to interest and talent--both yours and the students'.)

b. The instructor must use caution and try not to present too much technical information and terminology in this phase. If he delves deeply into the construction of the instruments, he may go beyond the capacity of some of his students. The primary object is for the student to learn the uses of the basic instruments. However, if a small group of capable students would like to tackle a project of this nature, certainly they should be encouraged.

c. In explaining anything concerning aerodynamics or flight navigation, the instructor should attempt to relate the subject to some similar activity the student has seen. It is usually profitable to "go to water" to explain many flight theories and terms. Indicated airspeed, true airspeed, and ground speed can easily be explained by imagining a small boat in a moving stream. Describe the boat as the airplane and the water as the air. If the stream is running five MPH and the boat is running 10 MPH down stream--the boat's (airplane's) waterspeed (airspeed) is 10 MPH--however, the groundspeed is 15 MPH. If the boat turns around and goes up stream with the motor pushing it at 10 MPH through the water, the boat's (airplane's) waterspeed (airspeed) is still 10 MPH. However, according to time and distance measurements, it has traveled over the stream bed only at the rate of five MPH (groundspeed).

d. One of the students will probably discover according to the above theory that if the stream is running at 20 MPH and the boat is going upstream at 10 MPH, the boat would actually be traveling backwards at 10 MPH. Not only is this possible during flight, but it has actually happened on several occasions in an airplane during the early days of flying.

e. When presenting material about the magnetic compass and the altimeter, you might want to visit your local support base, CAP, or airport fixed base operator to see if you could borrow one of these devices for classroom use.

f. An orientation flight would bring all of these elements into perspective. Have the students plan the flight using headings, altitudes, and airspeeds. Make them keep up with the various checks.

7. INSTRUCTIONAL AIDS:

   a. Attempt to get cutaways of instruments from local sources.

   b. Air Force Films:

      FTA 284 The N-1 Compass. 11 min, B&W, 1957.

      TF 5777 Basic Principles and Maintenance of Pressure Altimeters, 16 min, B&W, 1966.

      TFV 6441 N-1 Compass, 10 min, B&W, 1969.

   c. FAA Films:

      FA-209 One Eye on the Instruments, 16 min, color, 1962.

   d. Overhead Transparencies:

      V-1006 Flight Computer
      V-1007 Flight Computer, Wind Side
      V-1010 Pilot-Static System
      V-1011 Flight Instruments
      V-1016 FAA Flight Plan
      V-1019 Magnetic North Pole

8. PROJECTS:

Some good ones have already been mentioned, others are listed in the text under "Things to Do."

9. FURTHER READING:

See Suggestions for Further Readings in text. AFM 51-37 would be an excellent addition to your research library.

NOTE: Please use the next page to let us know of suggested changes or modifications for this phase of instruction.

AIR NAVIGATION

PHASE V

IDEAS FOR IMPROVEMENT OF THE TEXTBOOK AND/OR INSTRUCTOR'S GUIDE AND TEACHING TECHNIQUES MOST EFFECTIVE FOR THIS PHASE. TO BE COMPILED AT END OF TEXT AND SENT TO JRC

PHASE VI - DEAD RECKONING

The fundamental base of all navigation is Dead Reckoning (DR) procedures. Every flight uses some elements of dead reckoning. This phase begins by looking at the effect of wind on an aircraft. It then studies the six elements that go together to make up the wind triangle and the purpose the triangle serves.

1. PHASE VI OBJECTIVES: At the completion of this phase of instruction each student should:

   a. Know the meaning and use of dead reckoning.

   b. Understand the six factors of DR.

   c. Understand the effect of wind and motion on an aircraft.

   d. Be familiar with the construction and use of the wind triangle.

2. BEHAVIORAL OBJECTIVES: At the completion of this phase of instruction each student should be able to:

   a. Explain the meaning and use of dead reckoning.

   b. Explain the use of a navigation fix and navigation aids.

   c. Describe the effect of wind on an aircraft.

   d. Explain the factors affecting the path of an aircraft.

   e. Define drift and drift correction.

   f. Develop a wind triangle by combining the ground, air, and wind vectors.

   g. Figure one vector of the wind triangle given the other two.

3. SUGGESTED OUTLINE:

   a. DR definition and use

      (1) Navigation aids

      (2) DR factors

b. Aircraft path

(1) Wind effect

(2) Aircraft movement

(3) Track

(4) Drift

(5) Drift correction

c. Wind Triangle

(1) Vectors

(a) Component

(b) Resultant

(2) Air vector

(3) Ground vector

(4) Wind vector

4. ORIENTATION:

a. Normally dead reckoning is used in conjunction with pilotage or some other means of navigation. Rarely will a pilot/navigator depend solely on dead reckoning to navigate to his destination. On every flight, however, some elements of dead reckoning are used. Before a flight a flight plan should be developed and to do this the pilot must be able to apply dead reckoning procedures to figure headings and enroute time. In flight, conditions change. Wind shifts, detours around weather, route deviations due to malfunctioning equipment, etc., all demand that the flier refigure times and headings. This too takes a firm understanding of DR principles since the figuring must be done while flying the airplane. Safety of flight depends greatly on an understanding of DR.

5. SUGGESTED KEY POINTS:

** (V-9177) pp 100-102	a. There are two basic problems in navigation using dead reckoning: preflight and inflight. Preflight planning consists of using the chart and weather data to find distances and headings to destination. Inflight, indications from the instruments in the form of compass headings and in speeds can be used to determine the track and groundspeed being made good. From these the position of the aircraft can be found.
	b. There are four steps necessary to find the compass headings that will be followed to reach destination:
*** (V-9177) pp 102-103	(1) Plot the intended track(s) on a chart
	(2) Measure the True Course (TC)
* (V-9015) pp 288-291	(3) Apply wind effect to find True Heading (TH)
** (V-9013) pp 551-554	(4) Apply variation and deviation to find the magnetic and compass headings
** (V-9013) pp 556-558	c. At the same time that the headings are figured the groundspeed is determined so that time enroute and total fuel consumption can be figured.
(V-9177) p 111	d. Wolfgang Langewiesche is quoted in V-9177: "Then there is the wind. The air, the medium in which you move, is itself in motion . . . . whatever wind there is, even the slightest breeze, has its effect on you every single minute of flight. It distorts your curves, it falsifies your climbs and glides, it pulls your figure eights out of shape, it makes your ship go one way while its nose points the other way."
* (V-9002) pp 303-308, 317-318 * (V-9013) pp 560-562 ** (V-9161) pp 9-29 to 9-32 ** (V-9177) pp 107-128	e. The effects of wind can either be determined by constructing a wind triangle or by using a dead reckoning computer to solve the necessary vectors. Neither of these is difficult to learn.

f. To be extremely accurate in using dead reckoning the effect of climbing and descending must be taken into consideration. The winds for each 1000 ft of the climb and descent should be averaged. Using these with the average true airspeed the time and distance during the climb can be figured. As soon as the aircraft levels out a fix should be taken using pilotage or some navigation aid so that the DR can be started from a known position. A rule of thumb used quite often in light airplane flying is to add to the total time enroute, one minute for each 1000 feet of climb to cruising altitude.

*** (V-9177) pp 129-150

6. SUGGESTIONS FOR TEACHING:

a. Suggested time: 4-5-6 (Translation--if you teach two academic periods per week we recommend you devote four hours to this subject. If you teach three periods per week you could devote five periods. If you teach four academic hours per week you could devote six periods to the subject. These "Suggested times" are just that--recommendations. Adjust the emphasis according to interest and talent--both yours and the students'.)

b. We're back to some fun times. This block is another hands-on session. The instructor should be able to procure at least some of the tools and training aids for this lesson. This is probably the best place to go back to the Appendices and study the plotter and Dead Reckoning Computer.

c. Suggested Introduction of Lesson:

(1) This lesson could begin with the explanation that all students have used a form of dead reckoning if they have ever been on a trip in a car. If they were going to see "Aunt Lucy" and she lived 100 miles down Route 66, driving 60 MPH, but averaging only 50 MPH, and departing at 1000 hours, they would be there just in time for Sunday dinner.

(2) Now present them with a problem, they changed their mind and drove down the Interstate at 70 MPH (averaging 70 MPH), they would get there in time to help Aunt Lucy make final preparations for dinner.

(3) Now, using only pencil and paper, ask the students to figure out exactly how long it would take at 70 MPH. Some students will not even know how and probably most will take a long time to get the answer. This is the time to introduce the pilot's tools--computer and plotter, and show the students how they work by using the demonstration performance method.

d. The wind triangle problems can be solved easily on graph paper with a ruler and protractor which the school should have.

7. INSTRUCTIONAL AIDS:

a. Air Force Films:

TF 1-5206 A Wind and the Navigator--Wind Theory. 15 min, color, 1957.

TF 1-5206 B Wind and the Navigator--Preflight Planning. 15 min, color, 1957.

TF 1-5206 C Wind and the Navigator--Inflight Analysis. 8 min, color, 1957.

TF 1-5206 D Wind and the Navigator--Jet Streams. 15 min, color, 1959.

b. Any major oil company who supplies aviation fuel to the local airport gives away cardboard computers (without the windface) as an advertising gimmick. See the distributor in your area.

c. Your support base might be able to supply you with a sufficient number of computers and plotters. One for each student is not necessary. Students can easily work in groups. Don't forget that a straight slide rule can be used for navigational computations.

d. Overhead Transparencies:

V1006 Flight Computer
V1007 Flight Computer, Wind Side
V1013 Weather Map
V1014A Teletypewriter Weather Reports
V1015 Weather Station Model and Symbols
V1016 FAA Flight Plan
V1019 Magnetic North Pole

8. PROJECTS:

See "Things To Do" in the text.

9. FURTHER READING:

AFROTC/FIP, Dead Reckoning Computer Instructions, Maxwell AFB, Al: Air Force Officer Training Corps.

US Air Force AFM 51-37, Instrument Flying, Washington, D.C.: Department of the Air Force, 1971.

NOTE: Please use the next page to let us know of suggested changes or modifications for this phase of instruction.

AIR NAVIGATION

PHASE VI

IDEAS FOR IMPROVEMENT OF THE TEXTBOOK
AND/OR INSTRUCTOR'S GUIDE AND TEACHING
TECHNIQUES MOST EFFECTIVE FOR THIS PHASE.
TO BE COMPILED AT END OF TEXT AND SENT TO JRC

PHASE VII - NAVIGATION AIDS

Today almost all light aircraft are equipped with radio navigation aids. Just a few years ago this was not true. The technological advances in navigation have led the growth of the entire aircraft industry making navigation possible in any weather, at almost any altitude; indeed we can now navigate to the moon and back. This phase of instruction begins by putting the use of navigation aids and fixing in perspective with relation to dead reckoning. It then puts major emphasis on light aircraft navigation aids including aids in navigation to landing. This discussion is followed by a short survey of aids used in large, long range aircraft navigation.

1. PHASE VII OBJECTIVES: At the completion of this phase of instruction each student should:

   a. Understand how navigation aids combine with DR to solve the navigation problem.

   b. Understand the uses of VOR, VORTAC, ADF, and ILS.

   c. Be familiar with the uses of celestial, radar, LORAN, doppler and inertial navigation systems.

2. BEHAVIORAL OBJECTIVES: At the completion of this phase of instruction each student should be able to:

   a. Explain how DR and navigation aids are related.

   b. Define fix.

   c. Explain ADF homing procedures.

   d. Describe the use of VOR and its component parts.

   e. Differentiate between VOR, TACAN, and VORTAC.

   f. Describe an Instrument Landing System (ILS) approach to landing.

   g. Identify some military advantages of celestial navigation.

   h. Explain the procedures for obtaining a celestial fix.

   i. Explain the basic principles of radar navigation.

   j. Describe the use of LORAN.

k. Explain doppler effect and its application in navigation.

l. Describe the Inertial Navigation System (INS) and its use.

3. TEXTBOOK OUTLINE:

a. DR and navigation aids

(1) Fix

b. ADF

(1) Homing

c. VOR, TACAN, and VORTAC

d. Instrument Landing System (ILS)

e. Celestial

f. Radar

(1) Airborne

(2) PAR

g. LORAN

h. Doppler

i. Inertial Navigation System (INS)

4. ORIENTATION:

a. This phase of instruction tries to tie together the concepts covered previously with some of the modern aids to navigation. The major emphasis on operation is concerned with navigation aids that are used in light aircraft navigation.

5. SUGGESTED KEY POINTS:

* (V-9002) pp 315-316

*** (V-9177) pp 230-256

a. There is a method of radio navigation, not reported in the text, that has become obsolete. Low Frequency (LF) is still used in Europe and some places in the US. LF was replaced with ADF and quickly thereafter by VOR and VORTAC. ADF has some real disadvantages such as beam deflections in mountain areas. It also has a nasty habit of pointing toward thunderstorms that might be in the area.

b. You can plot a radial to or from a VOR station as well as an ADF station. There is one thing that must be remembered, all VOR bearings are magnetic, variation must be applied to obtain true bearings. For the VOR line of position (LOP) the variation at the VOR must be applied. When plotting an ADF LOP the variation at the aircraft must be used. LOPs may be taken from the pointers on the ADF or by centering the VOR CDI and reading the radial in the course selection window. Two or more stations can be used to get LOPs that cross and obtain a radio fix.

*** (V-9177) pp 173-174

c. Enroute high and low altitude charts are used primarily for radio navigation. They display only data used for instrument flight such as radio navigation aids, special use airspace, and some airports. They show no data such as lakes, rivers, cities, or roads that could be used for pilotage. This is done so that the IFR data and air route structure can be seen more easily. The enroute charts are based on Lambert conformal projections. The enroute charts should not be used for VFR flights. The symbols on an enroute chart do not resemble what they represent, therefore careful study of them is needed.

** (V-9177) pp 275-276

d. Identification Friend or Foe (IFF) was first used during World War II and is a small airborne transponder which transmits coded signals when triggered (interrogated) by a ground-based search radar. Pulses received from the airborne equipment produce "blips" on the ground-based radar scope and are used to positively identify and locate aircraft. The addition of a Selective Identification Feature (SIF) allows faster isolation and identification of any aircraft under surveillance. Positive identification can be established and maintained by the ground controller when a designated SIF "mode" and "code" is set into the airborne transponder. Initial identification is usually established by using the "IP" or "flash" function of the airborne set. Tracking is maintained by setting the requested mode and code into the airborne equipment. In the near future the function of this equipment will be expanded so that the altitude of the aircraft can be identified by the ground radar scope.

* (J-13) pp 601-610

e. Celestial navigation is normally used on long overwater or polar flights where radio aids, as well as distinguishable landmarks are non-existent. In this situation, (AFM 51-40, Vol 1) pp 11-1 to 19-14

a specially trained navigator becomes an absolute necessity. Few pilots are trained in celestial or LORAN navigation. Furthermore, the processes are so involved and time consuming that the pilot would not be able to do it and still handle his duties as a pilot. From the military point of view in case of attack, the enemy would not permit radio aids to remain in operation, therefore, a well trained navigator is an absolute necessity on a long-range combat mission.

6. SUGGESTIONS FOR TEACHING:

a. Suggested time: 2-4-5 (Translation--if you teach two academic periods per week we recommend you devote two hours to this subject. If you teach three periods per week you could devote four periods. If you teach four academic hours per week you could devote five periods to the subject. These "Suggested times" are just that--recommendations. Adjust the emphasis according to interest and talent--both yours and the students'.)

b. This phase is not meant to make navigators out of the student. If you enjoy some of the aids covered expand that section. If none of the students are thrilled about all this make this a quick survey phase.

c. The best method for teaching this phase is the demonstration-performance phase. Get the students to an airport or Air Force instrument shop and have them work with the actual instruments.

d. Get experts into the class to explain concepts you are not comfortable with. A local fixed-base operator or instructor pilot would be great to explain the use of VOR or ADF. An Air Force navigator would add reality to a discussion of celestial or LORAN.

7. INSTRUCTIONAL AIDS:

a. Air Force Films:

FTA 57	Radar Controlled Dead Reckoning Navigation. 10 min, B&W, 1955.
FTA 62 PTA	Periscopic Sextant--Part A--Nomenclature and General Application. 24 min, B&W, 1955.
FTA 62 PTB	Periscopic Sextant--Part B--Practical Application. 17 min, B&W, 1955.
FTA 356	Operational Techniques of LORAN Skywaves. 11 min, B&W, 1959.
SFP 1669	Flight Information Publications--FLIPs. 20 min, color, 1968.
SFP 2084	The Air Force Navigator--Nothing Like Columbus. 23 min, color, 1971.
TF 1-4932	VHF Omni-Range Navigation System. 21 min, B&W, 1954.
TF 1-4990	Primary Pilot Navigation--A Step in the Right Direction. 27 min, color, 1955.
TF 1-5041	The Pilot and Air Traffic Control. 28 min, B&W, 1956.
TF 1-5311	This is VORTAC. 12 min, B&W, 1958.
TF 1-5379 A	LORAN Navigation--Principles. 7 min, color, 1961.
TF 1-5379 B	LORAN Navigation--Readings. 7 min, color, 1961.
TF 1-5379 D	LORAN Navigation--Interference. 6 min, color, 1961.
TF 1-5381	Doppler Radar. 13 min, color, 1961.
TF 1-5383	Principles of Radar. 15 min, color, 1961.
TF 5502	Inherent Radar Errors. 21 min, color, 1963.
TF 5503	Low Altitude Radar Scope Interpretation--See What You Know, Know What You See. 20 min, color, 1963.

TF 5526 A — TACAN Systems--Operation and Theory. 15 min, color, 1963.

TF 5526 B — TACAN Systems--Troubleshooting. 10 min, color, 1963.

TF 5639 — Tactical Low Altitude Navigation. 20 min, color, 1965.

TF 5732 — Low Level Air Navigation Familiarization. 22 min, color, 1960.

TF 5741 — The F-4C Inertial Navigation System. 17 min, color, 1965.

TF 5756 — Modification of the Airway/Route System 1964. 14 min, color, 1964.

TF 5809 — Terrain Avoidance in Low Level Navigation. 31 min, color, 1967.

TF 6171 — F-111 Weapon System--F-111A Tactical Air Navigation System. 27 min, color, 1968.

TF 6174 A — F-111 Weapon System--F-111A Terrain Following Radar. 26 min, color, 1968.

TF 6220 — F-4 Phantom Instrument Flying and Navigation. 25 min, color, 1968.

TF 6276 — A-7D Operational Concept. 18 min, color, 1971.

TF 6316 C — F-111 Weapon System--FB-111 Computer Complex. 23 min, color, 1970.

TF 6316 D — F-111 Weapon System--Inertial Navigation System Theory. 19 min, color, 1970.

TF 6399 — Interceptor Airborne Radar Approach. 20 min, color, 1969.

TFV 6339 — APN-147 and ASN-35. 20 min, B&W, 1968.

b. FAA Films:

FA 02-70 — Area Navigation. 25 min, color, 1970.

FA 104 — This is VORTAC. 15 min, B&W, 1959.

FA 201 — What's My Traffic? 25 min, color, 1962.

c. Get some obsolete enroute charts.

8. PROJECTS:

Some good ones have already been mentioned, others are listed in the text under "Things To Do."

9. FURTHER READING:

See "Suggestions for Further Reading" in the text. AFM 51-37 would be an excellent aid in this phase.

NOTE: Please use the next page to let us know of suggested changes or modifications for this phase of instruction.

AIR NAVIGATION

PHASE VII

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