ing (vinylite or mylar) from the glass negatives of that map. This print is then used as a manuscript on which the revised details are drawn in black. The map revision may be done by graphic methods in flat areas, that is, by means of a radial plot and graphic delineation of details; in hilly areas stereoscopic instruments are used. The base maps are not completely revised for this purpose, but are used as a vehicle for obtaining the necessary corrections for charts.

A recent innovation in chart revision is the use of plastic scribing instead of drafting, where the revision reaches major proportions. After film positive copies of the basic planimetric or topographic maps are corrected from the latest photography, they are mosaicked on a controlled base. A blue line impression on yellow-coated vinylite is produced from this mosaic at chart scale; this can be scribed in approximately one-half the time needed to draft it and with a end-product superior in every respect. Plastic scribing is the subject of a separate paper by J. J. Streifler appearing elsewhere in this series.

Occasionally, photographic detail is so difficult to interpret that a field inspection for clarification is necessary. This condition is most commonly found in congested port facilities. A field party is dispatched to the site to make a thorough investigation and is supplied with a copy of the chart containing the corrections made by the compiler and photographs covering all the questionable areas. Upon completing the field work these data are returned to the compiler for application to the chart drawing. See illustration.

Illustration—Seattle, Washington. While the shoreline and large piers were readily discernible on the photographs, the small piers and piling in this area were almost completely obliterated by log booms, houseboats and smaller craft. Field inspection afforded the necessary clarification.

If a great deal of field work is to be done the supply of charts on hand may drop so low that it will be necessary to print a Tide-Over to bolster the supply until the chart is revised. This is a small reprint of the current issue without change.

Photogrammetry and the Safety and Regulation of Commercial Aviation

JOHN R. PATES, *Coast and Geodetic Survey*

ABSTRACT: *The Bureau's part in the compilation of airport approach and landing charts is described. The compilation and function of the present airport obstruction program is presented, including the special methods being utilized.*

THE practicing photogrammetrist, following the main highway of his science, is aware of many interesting byways which he probably has never had the time to explore. One such byway, which might not be familiar to him, is the role photogrammetry plays in the safety, reliability, and Federal regulation of commercial aviation.

Rules based on Civil Air Regulations and issued by the Civil Aeronautics Administration are mandatory and must be complied with by scheduled interstate air carriers, a category which includes the well-known air lines. In addition to covering the many phases of airline operation to which photogrammetry could have no relation, these rules require the airlines to prepare and keep current a manual for the use and guidance of flight and ground operations personnel. The minimum contents of this manual are specified and, as an example, must include, information on en route flight navigation procedures. This means that, among other things, the geographic positions of a multitude of electronic aids to navigation must be determined so that references to them can be included in the manual.

The role of photogrammetry thus begins

to emerge. To mention only one general class of navigation aid, there were in the United States at about mid 1956, 343 four-course radio ranges, one of the first types of radio aids to navigation. There were an additional 422 omnidirectional ranges, an improved aid. This improved aid, however, is considered only a transition toward an ultimate system known as Vortac. The installation of Vortac at 295 locations is scheduled by 1959. The goal for 1965 is that 1087 of these stations be in full operation. To supply the required geographic positions for all of these aids—both the older and improved types—in a relatively short time, is a tremendous task calling for the use of photogrammetry in conjunction with ground surveys, i.e., triangulation and traverse. Such a program is even now in progress and a great many of the required positions will be determined by stereoplanigraph bridging, utilizing recently developed methods of mathematical adjustment between existing ground control stations.

A brief historical background may be of interest at this point. A few years after World War I, when both air navigation and photogrammetry were embryonic, full information on aids to air navigation would have required little space in an airline manual, if such a manual had been available at that date. In 1921 the first night flight of air mail was completed from North Platte, Nebraska, to Chicago. The navigation aids for that historical flight consisted of an automobile road map, red flares, and bonfires. The first chart, prepared especially for air navigation, was not completed until the same year.

Five years later the Congress passed the Air Commerce Act of 1926 in recognition of the Federal responsibility for charting the airways. Because of the basic similarity between marine and air charting, the U. S. Coast and Geodetic Survey—which since 1807 had been charting the coastal waterways of the United States—was assigned the task of preparing and publishing aeronautical charts for civil aviation. In 1935 that agency completed a sectional aeronautical chart series, which constituted the first complete coverage of the United States on a uniform scale.

By 1939 some 27,000 miles of airways were marked with rotating light beacons—one of the first aids to air navigation—and four-course radio ranges, and 52 airports operated control towers for the regulation of aircraft on and in the vicinity of the airport. The air transport industry was growing, but still slowly.

It was World War II that gave aviation its tremendous impetus. In 1941, the air transport industry had grown to 227% of its 1937 size, but, at the beginning of the next decade (1950) the growth amounted to 1805%, and in 1953 to an amazing 3340%. To regulate and advance the safety of an industry growing with such giant strides has been a task in which photogrammetry has had and continues to play no small part.

As another example of this rapid development, in 1941 (at the beginning of World War II) the need became acute for a series of charts showing the existing airports and the immediate vicinity in considerable detail. The existing sectional aeronautical charts were at a scale of 1:500,000, and accordingly were inadequate. The U. S. Coast and Geodetic Survey was selected to prepare and publish the charts—later to become known as the approach and landing chart series—on a wartime priority basis. Quick production in volume, rather than precision, was the problem here. The intended use of the charts was to acquaint the mushrooming crop of wartime pilots with the runway patterns and with obstruction hazards at unfamiliar airports where landings might be required; to do this quickly might save young lives.

The charts were compiled from then existing Department of Agriculture photographs, most of which were at a scale of 1:20,000 and often four or five years old. Fast-moving field parties were organized and trained to field-inspect the photographs, supplement them with construction plans of the airport, identify critical obstructions and horizontal control, and determine obstruction and airport runway elevations. The field methods authorized were far from precise and compilation of the charts by slotted steel-templet radial plot (often with inadequate photography and control) may seem crude by today's standards.

Even though crude, this early photogrammetric method did provide the charts when the need was acute. About 550 for the more important airports were compiled from the photographs and the ground survey data. On one side of a letter size sheet, each chart comprised a plan of the airport and immediate vicinity at a scale of 1:31,680. The reverse of the sheet contained a planimetric map at a scale of 1:125,000 and covered a radius of some ten miles from the airport and showing the elevations of critical obstructions.

The experience gained during the war was of additional value. At its end civil aviation was at the threshold of its most tremendous growth. For the safety of a public, which had grown air minded, maximum take-off and landing weight-limitations for the air carriers were written into the Civil Air Regulations. To arrive at these limitations, it was necessary that both the air carriers and the Federal regulatory agencies have impartial, dependable, and accurate information about such matters as runway gradients and obstructions at airports where scheduled stops were proposed.

In June, 1945 the Administrator of the Civil Aeronautics Administration requested the Coast and Geodetic Survey to extend its wartime program of airport charting by commencing the preparation of a series of airport obstruction plans (see the illustration). That the task was begun none too soon is attested by the following quotation from the 1947 interim report of the Special Board of Inquiry on Air Safety appointed by the President:

> "The Board also wishes to note in this connection that accurate obstacle and profile maps are still not in existence for all airports now being used by these aircrafts. The making of these maps has for some time been a project of the Coast and Geodetic Survey, and encouragement and assistance should be given that organization for the rapid completion of that work."

The task has not yet been completed, although with the stimulant to production provided by photogrammetric methods, over 500 of the plans have been published. It is presently estimated that a large additional number of the plans must eventually be produced to cover all of the airports receiving airline service in the United States and Territories, and that all of these plans must be revised periodically to keep them current.

Unlike the approach and landing chart series, airport obstruction plans are not intended for use by the pilot and, indeed, he may be unaware that such plans exist. As stated above, the original purpose was to provide both the airlines and Federal regulatory authorities with dependable data for complying with Civil Air Regulations regarding maximum take-off and landing weights. The Regulation formulae for this purpose include such factors as the airport elevation above mean sea level, lengths and gradients of runways, and the elevations and distances of obstructions from the ends of runways. The maximum weight, as can be expected, varies with the type of the aircraft. The necessary calculations to determine the maximum weight for each aircraft are made, not by the pilot, but by engineers in the headquarters offices of the airlines, the Civil Aeronautics Administration, and the Civil Aeronautics Board.

Safety of life is obviously the prime consideration, but permissible loading is of intense economic interest to the airlines. The dollar consequences to the airlines of the gradient of a runway, or the elevation of an obstruction, or the number of feet from a runway end to an obstruction can be considerable in the course of a year's operations. Great accuracy and reliability in each obstruction plan is, therefore, essential for economic reasons as well as for safety.

During the years since 1945, refinements in, and very important secondary uses for, this series of plans have developed. One refinement has been the more exact definition of what objects constitute obstructions to air traffic. To arrive at such a definition is difficult; it is a problem still under study by such organizations as the Civil Aeronautics Administration and the International Civil Aviation Organization. At present, objects rising above rather complex imaginary surfaces are classed as obstructions, and the locations and elevations of these as well as the limits and intersections in space of the surfaces are shown on the plans. With this information, the plans fill an important additional purpose, namely, as a source for the data required to set up approved landing procedures (particularly for instrument landings) and for the zoning of the area immediately surrounding the airport. More comment with respect to these surfaces will be presented later.

It may first be interesting to discuss briefly the evolution in methods that has occurred to produce the presently required accuracy and production volume. Each obstruction plan (see the illustration) is essentially a large scale (1:12,000) map or plan of the airport and the area adjacent thereto on which are shown obstructions, with their elevations, as well as the surfaces that define an obstruction. A separate profile drawing for each runway and its approaches is also shown on each plan. Production of the plans entails these consecutive operations: aerial photography, ground surveys, photogrammetric compilation, drafting, and reproduction and printing.

The first plans were compiled by radial plot from photographs taken especially for this purpose. The plot supplied obstruction locations and airport detail. Runway and obstruction elevations, because of the rather tight permissible tolerance of $1\frac{1}{2}$ feet, were, and still are, determined by ground-survey methods. Flight lines were laid out parallel to the longest runway, and coverage was limited to the area extending to about three miles on all sides of the airport. The scale of the photographs was usually 1:24,000. Existing Federal horizontal control, where such control existed within the limits of the photography, was identified by the field survey party. This party also established additional control for the plot by a small triangulation net and, where feasible, this net was connected by a ground survey to the Federal triangulation net to supply an accurate horizontal datum for the plans. Basic vertical control was established by spirit leveling at the airport, and obstruction elevations were determined by trigometric leveling. Runway lengths were also determined by ground surveys. All of this required laborious and slow field work and, because of poor control spacing, the plot was often weak.

Gradually, these methods have been improved, primarily through the adoption of more precise photogrammetric methods, better planning and better quality photography. Photographs are generally taken with a Wild aviogon camera at a scale of 1:30,000 or 1:36,000. A single flight line will generally suffice at this scale, and the line is carefully planned to include sufficient Federal control. The photogrammetric plot usually consists of a stereoplanigraph bridge to provide basic horizontal position on the national datum. For delineation the Kelsh plotter is used.

Obstruction plans must be kept up to date, if they are to serve the intended purposes adequately. The operations for the required revisions are much the same as those for the preparation of the original plan; i.e. aerial photography, field examination, and photo-compilation. Stereoplanigraph bridging is not required in this instance, but if changes are numerous, the Kelsh plotter is used.

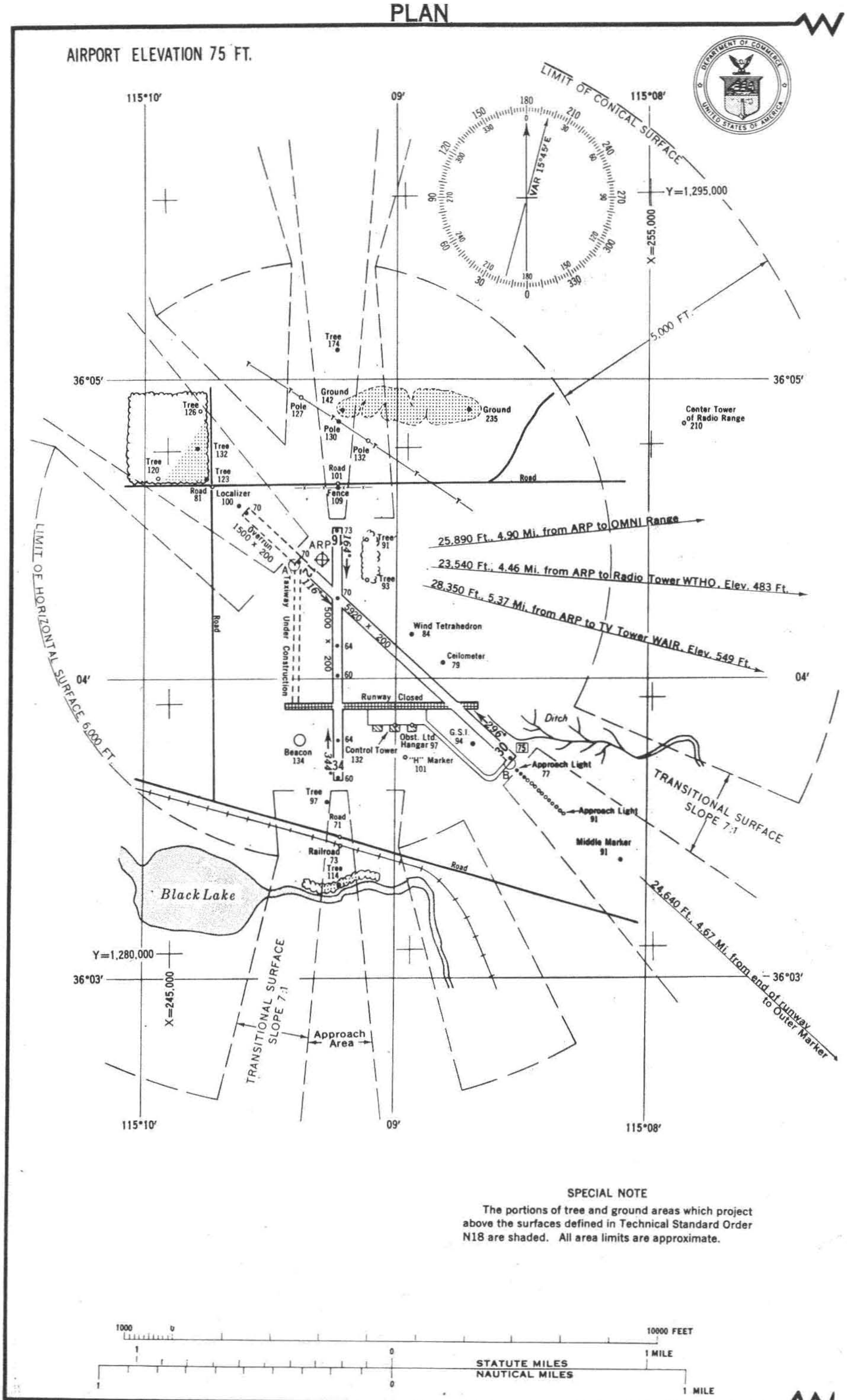
With the improved methods above outlined, the accuracy obtained makes possible the field work being reduced to little more than control identification, obstruction locations identification, and the determination of runway and obstruction elevations.

Further experimentation to improve accuracy and the rate of production is continually in progress, however. In this connection, extensive experiments were carried out in an attempt to obtain obstruction elevations by phototheodolite methods. It was found that accurate elevations for such as flagpoles, antennae, small stacks, and trees were impossible to obtain with any saving in time over the ground-survey methods regularly used. For this reason, use of the phototheodolite has been tentatively abandoned.

In conclusion, a few final comments on the uses of obstruction plans and the role of photogrammetry in the safety of commerical aviation seen appropriate. In a study of airport safety, a Presidential commission headed by Lt. Gen. James H. Doolittle (Ret.) investigated 31 crashes that occurred between 1946 and 1952 and resulted in injury or death to persons on the ground near airports. Of these crashes, 22 occurred within the fan-shaped areas designated as approach areas on obstruction plans (see illustration).

The case for presenting such areas on obstruction plans with the utmost care, so that safer zoning and approach procedures can be worked out, is further demonstrated by another report. This is a summary of 75 accidents that took place during attempted landing at airports in the years 1946 through 1955, and was prepared by the Bureau of Safety Investigation of the Civil Aeronautics Board. Of the total accidents covered, 26 were fatal and, in all except one case, the aircraft was destroyed. All but five of the fatal accidents occurred within

PLAN

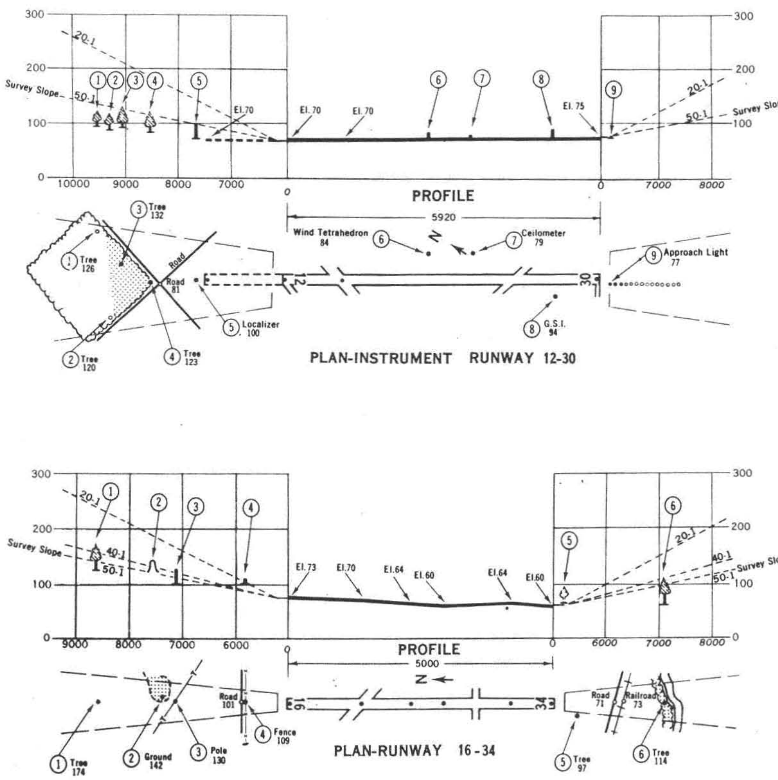


Surveyed and compiled by the Coast and Geodetic Survey, U. S. Department of Commerce according to joint specifications by the C & GS and the Civil Aeronautics Administration.

AIRPORT OBSTRUCTION PLAN

PROFILE

U. S. COAST AND GEODETIC SURVEY



OBSTRUCTION PLAN SPECIFICATIONS

Each Airport Obstruction Plan shows the runways, taxiways, and prominent airport facilities; frequently traveled roads and railroads in the vicinity of the airport; and the Approach, Horizontal, Conical, and Transitional Surface limits specified in Criteria for Determining Obstructions to Air Navigation, Civil Aeronautics Administration Technical Standard Order N 18.

Runway lengths shown are the maximum lengths available under the specifications set forth in Civil Aeronautics Administration Technical Standard Order N 6a for the classification assigned to the airport.

All elevations are in feet above mean sea level **and were determined by field methods to meet the following specifications:**

	ELEVATION TOLERANCE
Approach and Transitional Areas	1.5 feet per 5,000 feet from runway end
Runway Area	1.5 feet
Horizontal Area	3.0 feet within 5,000 feet of the Airport Reference Point plus 1.0 foot for each additional 1,000 feet
Conical Area	15.0 feet

HORIZONTAL SCALE 1:12,000

Polyconic Projection
Datum: N.A. 1927

AIRPORT REFERENCE POINT
LAT. 36° 04′ 23.7,″ LONG. 115° 09′ 17.7,″
ELEV. 71.4 FT.

LEGEND

- ⊕ .... Airport Reference Point (ARP)
- ▭ .... Official Airport Elevation
- ∘ .... Objects falling below imaginary surfaces
- • .... Objects projecting above imaginary surfaces

PROFILE NOTES

Objects falling just outside the Approach Areas are indicated by a broken symbol in the profiles.

Objects with a known base elevation have a short horizontal line at their bases.

The profile scale is as follows:

Horizontal .... 1 inch equals 1000 feet
Vertical .... 1 inch equals 100 feet

AIRPORT OBSTRUCTION PLAN

$2\frac{1}{2}$ miles of the airport, an area covered by obstruction plans. Such phrases as the following are common in the report and evidence the importance of obstruction surveys and approved approach procedures:

"... Pilot departed from standard (approach) procedure—Collide with trees..."

"Straight-in approach not approved for field was being made ... Struck tree ... "

"Evidence indicates pilot attempted to complete instrument approach by visual reference (not approved) ... Wing struck a 70 foot flagpole ... and fell off and the aircraft dived into a residence, with fire following."

These excerpts are from a cold statistical report. From even such meager detail, however, the imaginative reader can visualize scenes of heartbreaking tragedy. To make even one such report unnecessary is quite a challenge. The author believes that the photogrammetrist with imagination, devoted to that purpose, can play more than small part in meeting that challenge.

The Air Photographic Mission

LIEUTENANT ALFRED C. HOLMES,
Coast and Geodetic Survey

COAST and Geodetic Survey air photographic operations cover the United States and its territories, especially Alaska, and provide the specific types of photographs required for efficient mapping in support of nautical and aeronautical charts. These photographs are used for the production of large-scale base maps of the coastline as required for nautical charting, in revising nautical charts, in compiling and revising aeronautical Instrument Approach and Landing Charts, Airport Obstruction Plans, and for location of aids to marine and air navigation. Because of the rather unique requirements, this photography is taken by Bureau personnel with Bureau cameras.

A cooperative agreement has been in effect for a number of years between the U. S. Coast Guard and the Coast and Geodetic Survey whereby a Coast Guard airplane and flight crew are placed at the disposal of the Coast and Geodetic Survey, with the latter providing the photographic equipment, navigator, and photographer.

The singularly different piece of equipment, not used by any other air photographic team, is the nine-lens camera operated by the Coast and Geodetic Survey's Air Photographic Mission. This nine-lens camera was designed by Captain O. S. Reading of the Bureau to meet the specific requirements of coastal mapping.

The principal objectives in the design of the nine-lens camera were to obtain as great a coverage as practicable per photograph (to span water gaps) at the relatively large scales required for detailed mapping of the coast and alongshore features. This camera offers some problems in its airborne operation. First, because of its size (29 inches wide, 27 inches deep and 31 inches high), the camera requires an aircraft with a large compartment to give a photographer access to it from all sides. Secondly, because of its weight (750 pounds with all accessory equipment) the camera places minimums on the pay load and structural strength of the photographic aircraft. The size of the mirror cone and angle of view of the wing lens requires a minimum floor opening through the aircraft 24 inches in diameter. The lens cone must extend clear of the bottom skin of the aircraft when photographing, but must be retracked to prevent mirror damage when not in use. The size and weight of the camera require the installation of a winch to raise and lower it for photography, and to install and remove it from the aircraft.

The first installation of the nine-lens camera was made in a U. S. Army Air Force B-10-B-Martin bomber in 1936. The bomb-bay doors were removed and a temporary plywood floor with a sliding hatch was installed for mounting the camera. The near year the camera was installed in a U. S. Coast Guard BPY flying boat and later in a PBY-5A amphibious flying boat; with this, photography throughout the United States and Alaska was continued