NGS Protecting Against Airport Obstructions Socio-Economic Study

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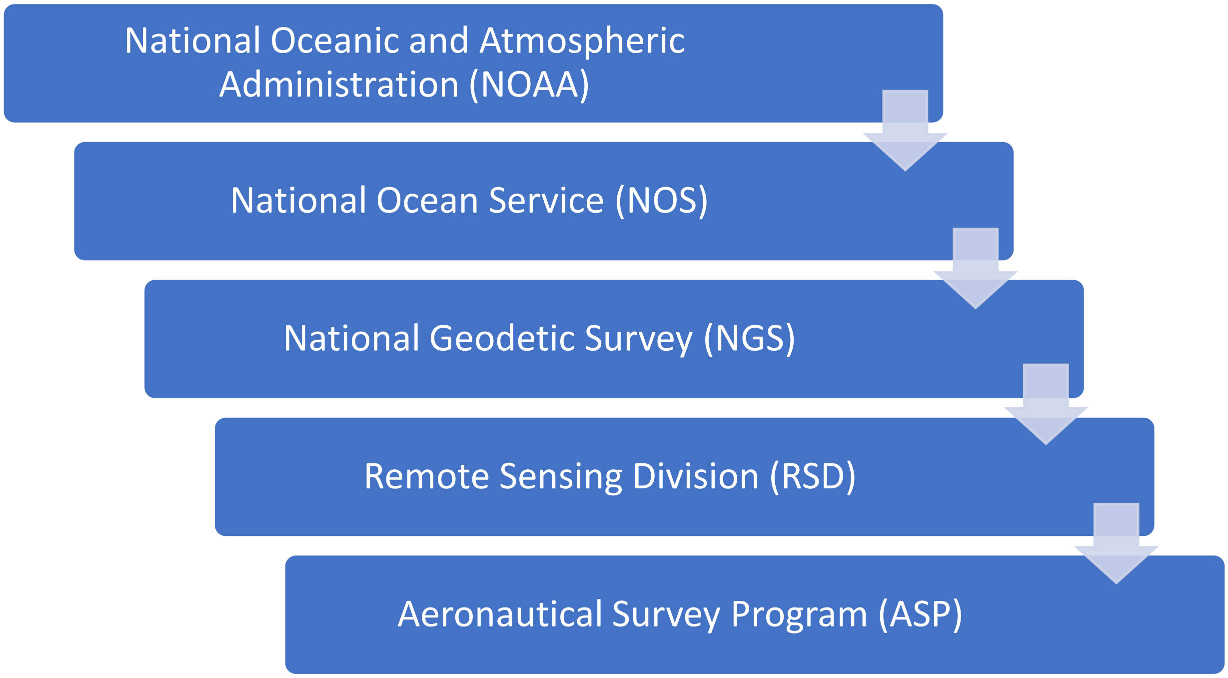


Protecting Against Airport Obstructions:

Socio-Economic Study of the NGS Aeronautical Survey Program

I. Summary

Objectives

This is a scoping study to provide a better understanding of the activity, uses, users and broader beneficiaries of the National Geodetic Survey's Aeronautical Survey Program, help define its socio-economic benefits, provide preliminary order of magnitude estimates of benefits of the program, and examine influences on future needs for the program's services. The footprint (trade space) analysis presents data on airport improvement grants, activities of the program, airports, aviation, and societal beneficiaries. Methods of estimating socio-economic benefits are considered, preliminary estimates of benefits are made and issues that will affect use of the services in the future are discussed. Additional information is included in 10 appendices.

The FAA Airport Improvement Program and the NGS Aeronautical Survey Program

The FAA Airport Improvement Program (AIP) provides grants, to public agencies for planning and development of the 3,249 eligible public-use airports and the 72 privately owned civil airports that are included in the National Plan of Integrated Airport Systems (NPIAS). For large and medium primary hub airports, AIP capital improvement project grants cover 75% of eligible costs or 80 percent for noise program implementation. For small primary, reliever, and general aviation airports, the grants cover 90-95% of eligible costs.

FAA requires that geographic information system (GIS) contractors submit plans and surveys with geodetic control, runway, navigational aid, obstruction, and other aeronautical data under its Airports GIS (AGIS) program. The surveys are funded through FAA regional offices to sponsors which may be airports, local government owners of airports or other entities. The sponsors engage private contractors to conduct the GIS surveys. The survey plans and surveys are sent to the NGS Aeronautical Survey Program (ASP) for quality assurance review.

The NGS Aeronautical Survey Program (ASP) operates within NOAA's National Geodetic Survey (NGS) under contract to FAA to review and validate the safety aspects of U.S. airport obstruction survey plans and surveys done by private contractors. ASP performs various related functions as well. The GIS information is used by FAA in establishing flight rules and other requirements to assure safety.

Benefits of the Program

The Nature of Benefits

Efficient use of the national airspace is essential for the public and for our highly interdependent local, national, and international economic activities. Without valid airport obstruction surveys. FAA imposes restrictions that require aircraft to land with less efficient flight paths, restricts access to runways, or sets other limitations. Airport GIS surveys are required for instrumentation that allows flying in severe weather. Flight instrumentation rules allow reduced aircraft, passenger, and cargo time, save fuel and other costs, and can reduce noise and pollution.

All-weather flying has important economic benefits to airports, airlines, passengers, cargo shippers and industries that depend on them. Without all-weather flying more flights would be cancelled, delayed, or diverted to other airports. All weather flying is a major benefit to many small communities that depend on their flights to maintain relationships with people and businesses around the country and abroad. Moreover, smaller airports are being viewed as an alternative to major airports when required by security, congestion, or other conditions.

Preliminary Estimates of the Value of the NGS ASP Program

Approach

Scenarios describing conditions in the absence of the NGS ASP are developed recognizing that FAA is not expected to conduct its Airport Improvement Program without any survey capability. Preliminary order of magnitude estimates of the value of the ASP program's review of contractor plans and surveys are made under alternative scenarios representing:

1) Complete loss of benefits in the absence of the program, and

2) 10%-20% loss of benefits under an alternative arrangement that is 80%-90% as effective in term of capability, timeliness and/or cost. Two illustrations of possible operations in alternative settings are described.

Preliminary order of magnitude estimates of the loss of benefits of ASP's principal review and validation functions in 2019 are made for five overlapping components using diverse methods and data sources. The fifth component of the estimates which accounts for the majority of benefits applies directly to ASP. For the remaining components, portions of benefits of broader measures are allocated to ASP. The component estimates are presented as illustrative ranges of possible magnitudes. They are:

1. Savings from use of WAAS
2. Fuel cost savings with continuous descent arrivals (CDA)
3. Reduced cost of flight delays due to weather with ILS
4. Value of passenger time saved with reduced flight delays due to airport improvements
5. Benefits of increased airport connectivity

There is great variation within and between the estimates, overlap among them, and considerable issues of data quality. In some estimates this results in the need for assumptions requiring judgement about reasonable magnitudes of the relative contribution of ASP vs. other influences. Consequently, wide ranges are used for the component estimates and the breadth of these ranges is reflected in the overall estimates. Estimates of the program's impact on jobs are also made.

Benefit Estimates

Preliminary estimates of the benefits of principal services of the ASP program are made for direct benefits and full benefits. Full benefits include multiplier effects on suppliers and direct and indirect benefits throughout the economy. The estimates apply only to the parts of airports that benefitted from ASP reviews that took place in 2019. Present discounted values for 2020-2029 are calculated to show the value in 2019 of cumulative benefits of the program continuing on the same basis for a decade.

The direct benefit estimates for the complete loss and partial loss scenarios in 2019 are presented in Figure S-1, along with the total loss values that include multiplier effects on the economy. The total loss of the incremental economic value of the main activities of the program ranges between $344.3 million and $1.53 billion in 2019 under the full loss scenario while under the partial loss scenario it is between $34.4 million and $306.0 million.

Figure S-1. Benefit Losses in 2019 Under Complete and Partial Loss Scenarios

direct

- Full loss of incremental value: $230 million - $1.02 billion
- Partial loss of incremental value: $23.0 million - $204.5 million

total (with multiplier)

- Full loss of incremental value: $344.3 million - $1.53 billion
- Partial loss of incremental value: $34.4 million - $306.0 million

The present discounted values of the full benefits of the main ASP services over 2020-2029 are calculated for the year 2019 including multiplier effects and allowing for growth with the economy. The discount rate of 7% above inflation recommended by OMB is used. The rate is intended to reflect risk as well as compensation for delayed returns. Lower discount rates for which benefits would be higher are shown in the body of the report. The present values of benefits of the NGS ASP program in 2019 under the two scenarios are:

Table S-1. Present Discounted Values of Full and Partial Benefits at 7%	
Present value of full loss of incremental value	$3.0 billion - $13.2 billion
Present value of partial loss of incremental value	$295 million - $2.6 billion

The wide variation in each case reflects the use of several methods and uncertainty in the data. However, at a minimum, under the full loss scenario the present value of the program over the next decade is in the billions of dollars and under the partial loss scenario it is in the hundreds of millions of dollars. This compares with a current program cost of less than $3 million per year.

The loss of jobs without the NGS ASP program is calculated using a national ratio of value added to jobs and allowing for a lower ratio of value added to jobs for incremental changes. The direct loss of jobs under the full loss of incremental value scenario is estimated as 2,292-8,566. Under the partial loss scenario the direct reduction in jobs is 230-1,714. Including multiplier effects using a multiplier of 1.5 for incremental changes, the reduction in jobs without the program is estimated as 3,438-12,849 under the full loss of incremental value scenario and 345-2,571 under the partial loss scenario.

Safety and environmental effects vary. If runways and other facilities could not be used because surveys had not been approved there would be fewer flights and aggregate safety data would be more favorable. It is not clear how or how much safety measures per flight would be affected.

Air pollution under restrictions could come from greater use of fuel per flight with less efficient landings and takeoffs and longer flight paths. However, weight limits would reduce use of fuel. With restrictions, fewer flights would take place as a result of higher costs and the inability of some planes to land and take off in bad weather, which would mean less total use of fuel. With restrictions there also would be more noise with additional time in the air due to longer landing paths, more circling and more missed approaches.

Influences on Future Needs for the Program

The overall outlook for U.S. aviation and for the U.S. economy was for slow growth even before the coronavirus outbreak and deep recession. Also, the movement to NextGen and improved aviation weather forecasting has been slow, as has been movement toward increased use of instrument landing systems among smaller aircraft.

Most investment in airports was expected to be in terminals and not directly in increased flight capacity. Other areas of investment may receive attention including facilities for UAVs and air taxis, spaceports, and facilities in support of the new Space Force. Some of this activity will require airport obstruction surveys that benefit from the services of the NGS Aeronautical Survey Program.

Consolidation of firms capable of doing airport obstruction surveys could be hastened by weak initial and ongoing demand for runway construction and renovation. A national infrastructure program could cause demand to be further concentrated among the most capable firms. To the extent this occurs it could reduce the need for as many ASP reviews of the same projects. However, demand for services of the program could increase initially with a national infrastructure program and with survey firms' learning to adapt to the new NSRS which is scheduled for 2023.

Further considerations in thinking about future needs noted include the following:

- It has been suggested that it could become more important for surveys to check for cell towers and radio transmission towers that, despite being regulated, can slip through unreported.
- The extensive use of LIDAR by FAA offices and FAA approval of use of satellite imagery by contractors are not expected for a considerable time.
- More frequent surveys could become necessary if sea level rise and/or extreme weather raised risks of fire, flooding, or growth of foliage, or if a there was large or threatening increase in construction near airports.

II. Introduction

The Program and Its Context

The FAA Airport Improvement Program

The Airport Improvement Program (AIP) provides grants, to public agencies, generally of cities, counties or states, for the planning and development of the 3,249 eligible public-use airports and the 72 privately owned airports in the FAA's National Plan of Integrated Airport Systems (NPIAS).[1] Grants are made only to airport sponsors and not tenants. A list of eligible and ineligible types of projects is in Appendix F.

For large and medium primary hub airports, AIP capital improvement project grants cover 75% of eligible costs or 80 percent for noise program implementation. For small primary, reliever, and general aviation airports, the grants cover 90-95% of eligible costs. Other sources of funding include federal state and local government grants, bonds, passenger facility charges, landing and terminal fees, and parking, aviation fuel and concession charges. In the largest and busiest airports, most capital improvements are funded by nonfederal sources.[2]

FAA estimates a need for $35.1 billion in eligible airport projects between 2019 and 2023. The agency recommends that capacity planning start when aircraft activity reaches 60-75% of airport capacity to allow time for planning, approval, and construction.[3]

FAA standards and guidelines are mandatory for projects funded under Federal grant assistance programs, including the Airport Improvement Program (AIP). FAA requires that geographic information system (GIS) contractors submit plans and surveys under its Airports GIS (AGIS) program. The surveys are funded through FAA regional offices to sponsors which may be an airport, local government owner of an airport or another entity. The survey plans and surveys are received by FAA and sent to the NGS Aeronautical Survey Program (ASP) for review of safety aspects.[4]

FAA imposes restrictions in the absence of approved surveys that can include:

- Restricted or denied use of a runway
- A buffer added to height in landing approaches
- Step down and/or longer landing approach; possibly more circling required
- Flight procedure delayed or withdrawn, including authorization for use of instrument landing systems which are required for all-weather flying
- Allowed takeoff weight reduced

[1] NPIAS airports include 7 that are proposed. U.S. Department of Transportation, Federal Aviation Administration, *National Plan of Integrated Airport Systems (NAPIS)*, Report to Congress, September 26, 2018, pp.3-4 https://www.faa.gov/airports/planning_capacity/npias/reports/media/NPIAS-Report-2019-2023-Narrative.pdf
[2] *Ibid*. pp. iv-v.
[3] *ibid*, p. iii.
[4] *ibid*., p.17.

The NGS Aeronautical Survey Program

The NGS Aeronautical Survey Program (ASP) is an FAA-funded program in support of the FAA Airports Surveying Geographic Information System (Airports GIS or AGIS) Program which operates in the NOAA National Ocean Service under the National Geodetic Survey (NGS) Remote Sensing Division.

The FAA AGIS program requires the collection and validation of airport geodetic control, runway, navigational aid, obstruction, and other aeronautical data which is critical to the safe operation of the National Airspace System. The focus of ASP is on the safety aspects within the FAA's extensive requirements. Most of the ASP program's efforts involve quality assurance review of the survey and quality control plans and review of the surveys performed by the FAA contractors.

ASP's full range of functions include:[5]

- Validating Geodetic Control Plans and Geodetic Control Data collected and submitted by commercial surveys through the Airports Surveying GIS Program under the FAA Airport Improvement Program (AIP)
- Validating geo-referenced aerial imagery collected and submitted by commercial surveyors through the Airports GIS Program
- Validating survey/safety critical data collected and submitted by commercial surveyors through the Airports GIS Program. The survey data includes both airport and obstacle information
- Adding data from NGS and other National Ocean Service sources
- Generating files in UDDF format for FAA use
- Verify obstacles as non-existent that contractors report by number in the FAA obstacle database and forwarding the information to FAA
- Responding to obstacle verification requests
- Re-reviewing control data and entering it into the NSRS for public use

Text Box 1. Independent Validation and Verification of Airport Safety Data

FAA defines the role of the NGS ASP program and use of its findings as follows:

"Due to the critical nature of some airport features, the FAA requires their independent verification and validation by the Aeronautical Survey Program of the National Geodetic Survey or a designated representative. Typically, these features are those associated with the airport's movement areas, navigational systems or those affecting navigable flight such as objects surrounding the airport. Once the independent verification, validation and quality assurance of the safety critical data is completed, the government technical representatives will provide a complete final written analysis of their findings including approval or disapproval of the data. They will identify and list any discrepancies discovered relating to these specifications and decide on the usability of the data."

U.S. Department of Transportation, Federal Aviation Administration, *150/5300-18B - General Guidance and Specifications for Submission of Aeronautical Surveys to NGS: Field Data Collection and Geographic Information System (GIS) Standards*, May 21, 2009, p.9 https://www.faa.gov/regulations_policies/advisory_circulars/index.cfm/go/document.information/documentid/74204

[5] For details on the process see https://www.ngs.noaa.gov/AERO/aero.html An earlier detailed analysis of the Aeronautical Survey Program's operations is contained in Elizabeth A. McQueen, *Independent Assessment of the Airport Surveying – Geographic Information System (AGIS) Program*, MITRE Corporation, draft, August 2009.

- Providing standards and guidance documents as inputs for FAA circulars
- Providing data for control tower analysis in support of control tower siting and air traffic controller training

The FAA benefits from ASP's comments on surveys and denial of submissions of vendors that are not qualified. The FAA also benefits from the guidance survey firms receive in the course of reviews, the knowledge from which can speed approval and save time in present and subsequent surveys for contractors and ASP.

The program reviews submissions to determine if they meet FAA specifications as spelled out in its Advisory Circulars:[6]

geodetic actual plan data	Circular AC16
imagery data	Circular AC17
final survey data	Circular AC18

Circular AC18 includes the standards and specifications for surveying to obtain runway, navigation aid and obstacle data.

The NGS ASP program receives digital obstacle data from FAA. ASP may be asked to check data for positional accuracy that FAA has received from another source.

Text Box 2. Uses of ASP Information as Stated in the NGS Strategic Plan

The program meets Objective 1-2 of the NGS 2019-2023 Strategic Plan (p.15): "Maintain the operational capacity of airport surveying to support airport infrastructure." The Plan states that:

> "The FAA uses our ASP information to establish instrument approach and departure procedures, determine takeoff weights, and update aeronautical publications."
>
> "This information is also used for airport planning and construction studies."
>
> "ASP also supports the FAA by developing standards and guidance documents for conducting aeronautical surveys."

U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Geodetic Survey, *National Geodetic Survey Strategic Plan, 1919-1923* https://www.ngs.noaa.gov/web/about_ngs/info/documents/ngs-strategic-plan-2019-2023.pdf

ASP has a large library of digital imagery that the program has reviewed. FAA doesn't store all the imagery. At times, the ASP program can use the data instead of getting new imagery. ASP also collects aerial image data on airports in the NGS Coastal Survey Mapping Program for its use.

[6] U.S. Department of Transportation, Federal Aviation Administration, *150/5300-16B - General Guidance and Specifications for Aeronautical Surveys: Establishment of Geodetic Control and Submission to the National Geodetic Survey*, July 8, 2019 https://www.faa.gov/airports/resources/advisory_circulars/index.cfm/go/document.current/documentNumber/150_5300-16, U.S. Department of Transportation, Federal Aviation Administration, *150/5300-17C - Standards for Using Remote Sensing Technologies in Airport Surveys (Consolidated to Include Change 1)*, September 30, 2011 https://www.faa.gov/airports/resources/advisory_circulars/index.cfm/go/document.current/documentNumber/150_5300-17 and U.S. Department of Transportation, Federal Aviation Administration, *150/5300-18B - General Guidance and Specifications for Submission of Aeronautical Surveys to NGS: Field Data Collection and Geographic Information System (GIS) Standards*, May 21, 2009 https://www.faa.gov/regulations_policies/advisory_circulars/index.cfm/go/document.information/documentid/74204

The NGS ASP program reviews of geodetic surveys often address structures near airports that have been present for many years. However, they also include lighting and foliage and temporary obstacles such as construction cranes used in the airport's own development.

The ASP program converts contractor files and other data to UDDF text format, Without the conversion more limited use would be made of the survey information by the FAA because some FAA offices rely on LiDAR but are unable to handle the various formats used in the consultant surveys.

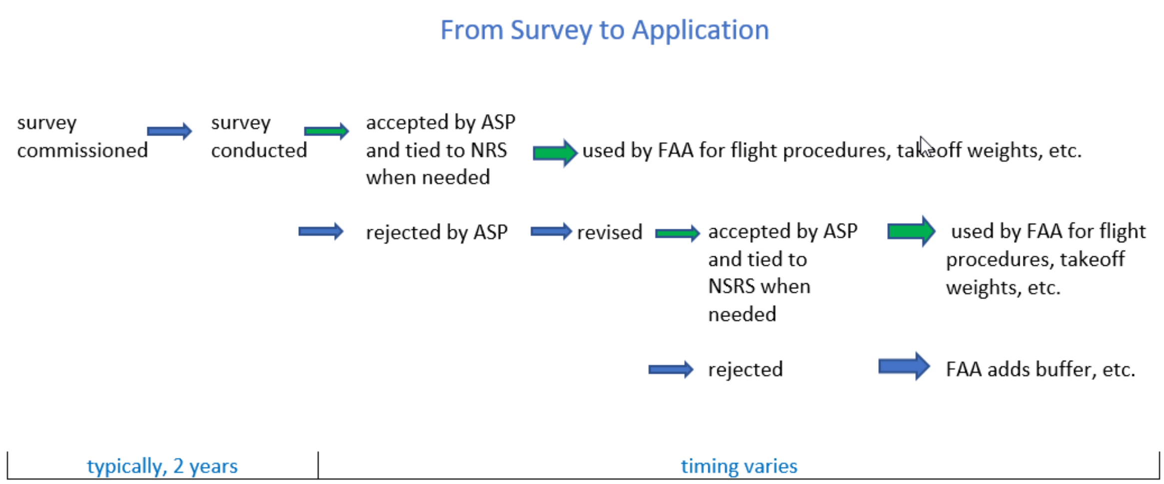
In addition to the survey review functions in the NGS Remote Sensing Division, the Observation and Analysis Division (AOD) field operations branch in Norfolk, VA does further quality reviews of the AC-16 plans and data to assure they are ready to be entered into the National Spatial Reference System (NSRS). The data for control stations entered into the NSRS is then available to all users.[7] The Observation and Analysis Division provides data used for control tower siting and air traffic controller training. AOD also can conduct occasional special surveys for FAA on request.

Despite all of its functions, the NGS Aeronautical Survey Program operates with a budget of less than $3 million per year.

From Survey to Application

Once approved by ASP, survey plans and airport obstruction surveys are used in FAA decisions. Plans and surveys that are rejected are usually resubmitted, sometimes multiple times, until they are approved and available for use by FAA. When plans are unavailable, FAA may add a buffer to the flight path for the runway, restrict the runway's use, or apply other restrictions. The process for commissioning and conducting surveys alone typically takes two years (Figure 1).

Figure 1



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[7] Most of the projects NGS reviews don't require Primary Airport Control Station and Secondary Airport Control Station data (PACS & SACS) since FAA no longer requires them, but those data still go into the NSRS.

Study Objectives and Process

The study has the following objectives:

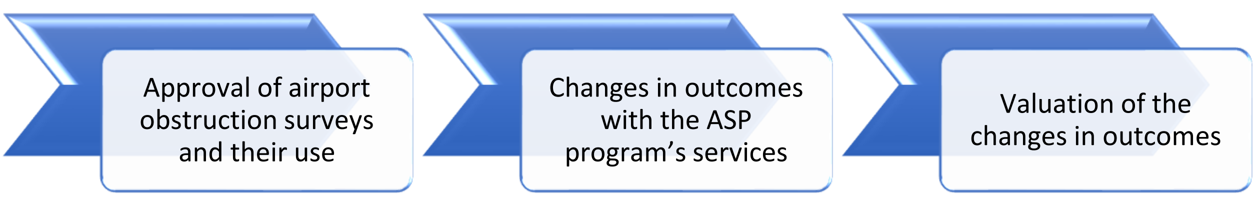
- Provide better understanding of the uses, users and broader beneficiaries and of the products and services of the program
- Help define the socio-economic benefits of the products and services
- Quantify the orders of magnitude of the benefits of the program
- Assess influences on future needs of those using the program's products and services

It addresses five questions which the NOAA National Ocean Service has used as a template for socio-economic studies for over a decade.

1) Who benefits from NOAA's NGS Aeronautical Survey Program?
2) What is the nature of these benefits (how are these benefits accrued)?
3) What methodology is appropriate to best estimate the value of NGS Aeronautical Survey Program services to these users?
4) What are the preliminary estimates of the distinct value for NGS Aeronautical Survey Program services?
5) How many jobs do Aeronautical Survey Program products and services support?

Benefits ultimately depend on the outcomes which result from FAA use of the airport obstruction surveys and the valuation of those outcomes (Figure 2). FAA approvals obviate the need for restrictions and allow more efficient flights and use of the national airspace. The decisions produce outcomes that affect airports, aircraft, crew, passengers, cargo, communities, and the nation.

Figure 2. Valuation



Estimates of the value of benefits of the ASP program are based on 5 measures built on data from several sources which are combined into an overall range for the value of total economic benefits.

Future needs of those using the Aeronautical Survey Program's products and services are explored in discussion of developments including:

- Changes in aviation technologies and markets
- Airport surveying and infrastructure development in the aftermath of COVID-19 and the 2020 recession

- The new NSRS to be released by 2023 and geodetic surveying
- Growth of communications towers
- The extent of FAA use of Lidar
- The future importance of satellite imagery
- Contributions of ASP elevation data to dealing with possible effects of increases in extreme weather and sea level rise

III. Footprint Analysis

Applications and users are examined in a footprint analysis which brings together data on operations of the program and quantitative and qualitative information on the environment which it impacts. The discussion moves from overall airport capital expenditures to government grants for airport infrastructure. Internal data on the program is examined to provide understanding of the scale of its efforts. The footprint analysis explores how the program's benefits arise and provides data on users and ultimate beneficiaries. Data from FAA, other government, industry, and academic reports are examined, and information is obtained through interviews with NGS, FAA, airport, and industry personnel. Additional information is provided in appendices.

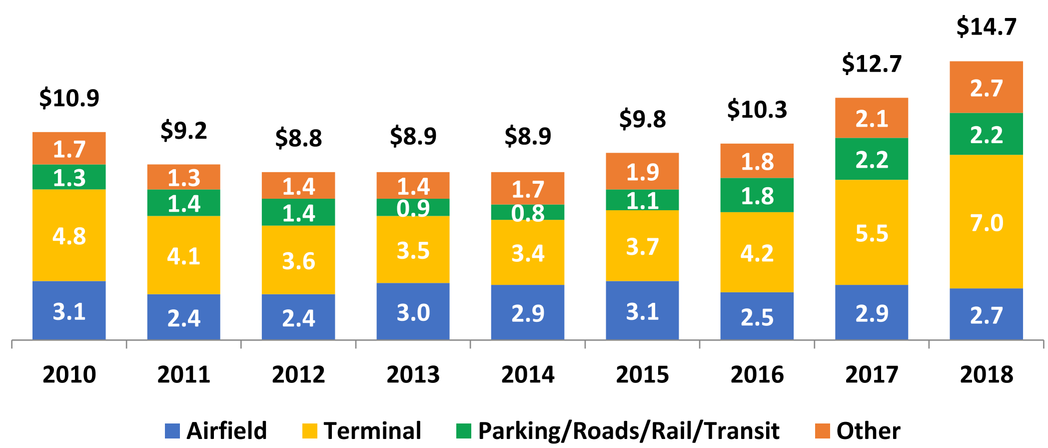
Airport Capital Expenditures

Overall Airport Capital Spending

Airlines for America reports that capital expenditures for commercial service airports funded by all sources was $14.7 billion in 2018, up from $8.9 billion in 2014 (Figure 3). Terminal facilities make up half of capital expenditures for commercial service airports and their share has been growing rapidly. Airfield spending was $2.7 billion in 2018, less than one-fifth of all capital spending and the lowest percentage in a decade. The share of airfield spending is expected to remain relatively low because of the continuation of interest in terminal, parking and transportation and other features.

Figure 3. Capital Expenditures for U.S. Commercial-Service Airports, 2010-2018

($ billions)



Source: Airlines for America, "Industry Review: Allocating Capital to Benefit Customers, Employees and Investors," updated February 19, 2020, slide 33 https://www.airlines.org/dataset/a4a-presentation-industry-review-and-outlook/

Public Spending on Airport Infrastructure

Federal and state and local governments spent (an unduplicated) $10.4 billion on airport infrastructure in FY2017. The federal government spent $5.5 billion while state and local governments spent $5.9 billion and directed spending of $3.2 billion of the federal and their own funds (Table 1). These funds are critical to additional government spending of $25.7 billion on operations and maintenance as well as spending by the private sector.

Table 1. Public Spending on Airport Infrastructure by Type and Level of Government, FY2017
(billions of year 2017 dollars)

Type of Spending and Level of Government	Capital	Operations and Maintenance	Total
Federal grants and loan subsidies for infrastructure	**3.1**	0	3.1
Other federal spending on airport infrastructure	2.4	11.3	13.6
Federal total	**5.5**	**11.3**	**16.8**
Total State and local spending on airport infrastructure	9.1	14.4	23.4
State and local spending on airport infrastructure net of federal grants and loan subsidies	5.9	14.4	20.3
Net total of federal and state and local spending on airport infrastructure	**10.4**	**25.7**	**37.1**

Source: Congressional Budget Office, *Public Spending on Transportation and Water Infrastructure, 1956-2017*, October 2018 and supplemental tables https://www.cbo.gov/publication/54539

Airport Improvement Grants

Airports in the National Plan of Integrated Airport Systems (NPIAS) are eligible for federal grants under the Airport Improvement Program. NPIAS airports accounted for 99.96% of total aircraft operations in calendar year 2016.[8] 2,726 grants were made in FY2019, 688 of which were for construction and reconstruction alone (Table 2). Some of the grants in the "all other" category also are subject to ASP review. Grants are widely distributed among uses and regions (Figure 4). Types of projects eligible for Airport Improvement Grants are listed in Appendix F.

[8] U.S. Department of Transportation, Federal Aviation Administration, *National Plan of Integrated Airport Systems (NAPIS)*, Report to Congress, September 26, 2018, p.4 https://www.faa.gov/airports/planning_capacity/npias/reports/media/NPIAS-Report-2019-2023-Narrative.pdf

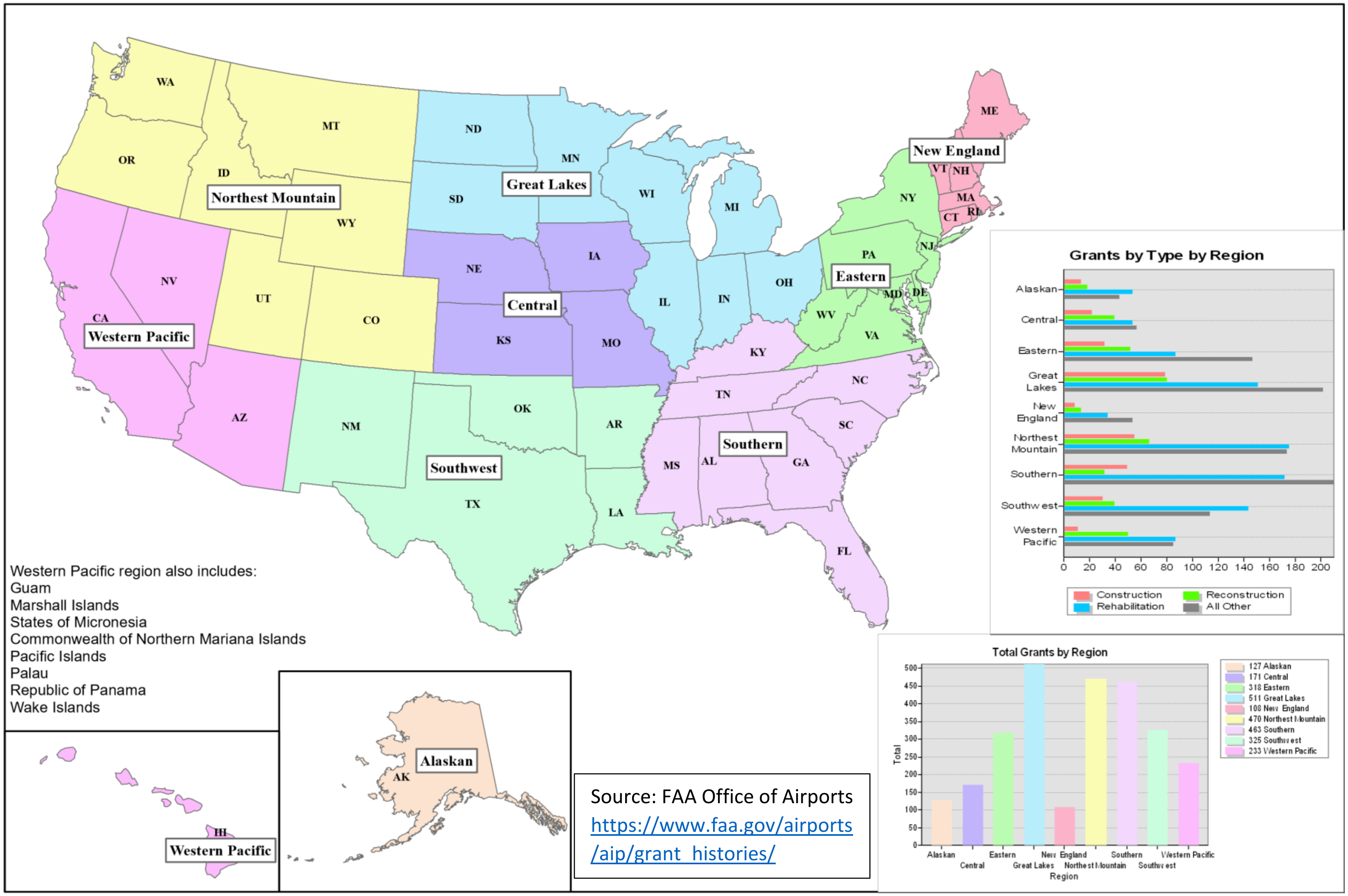
Table 2. Number of Airport Improvement Program Grants by Type and Region, FY 2019

Region	Construct	Reconstruct	Rehabilitate	All Other	Total
Alaskan	13	18	53	43	127
Central	22	39	53	57	171
Eastern	32	52	87	147	318
Great Lakes	78	80	151	202	511
New England	8	13	34	53	108
Northwest Mountain	55	67	175	173	470
Southern	49	32	172	210	463
Southwest	30	39	143	113	325
Western-Pacific	11	50	87	85	233
Total U.S.	**298**	**390**	**955**	**1,083**	**2,726**

Note: Construct, reconstruct and rehabilitate only refer to facilities in the purview of ASP reviews.
Source: https://www.faa.gov/airports/aip/grant_histories/

Figure 4

Airport Improvement Program Grants by Type and Region, FY 2019



Source: FAA Office of Airports https://www.faa.gov/airports/aip/grant_histories/

ASP Program Activities

ASP reviews survey plans and surveys that support airport planning studies costing perhaps $8-$15 million dollars per year (Appendix G). The benefits of the program flow from the activities in which ASP is engaged, the FAA actions it enables, and the consequences of those actions for airports, aviation, and the economy.

FAA requirements for coverage of safety critical data are listed in Appendix E. Data specified in FAA advisory circulars (AC) are examined by contractors funded through FAA regional offices to airports, localities, and other sponsors. Types of data and ASP downloads are shown in Table 3. ASP had 630 downloads in FY 2019. These include multiple submissions for a single project, both because of the several components and because of resubmissions due to incompleteness or error.

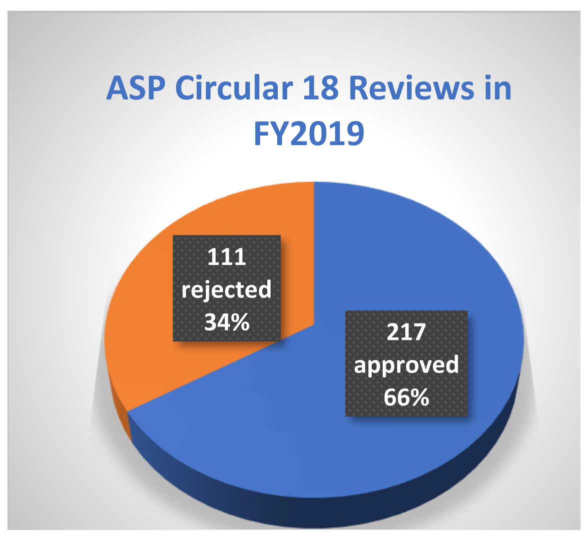
Table 3. ASP AGIS Data Downloads by Type, FY 2019	
AC-18 Survey Data	353
AC-17 Imagery Data	228
AC-16 Geodetic Control Plan	21
AC-16 Geodetic Control Data	28
Total	**630**

Rejection rates were 34% in 2019 (Figure 5). They were lower on resubmissions than on initial submissions but were still high.

The extent of incomplete or incorrect data submitted to ASP is evident in its workload:

- 45% of the AC-18 surveys reviewed were approved the first time they were submitted
- 32% of the AC-18 work was reviewing resubmitted data
- 34% of the AC-18 work was on surveys that were rejected

Figure 5. Approval Rate



- 12% of the AC-18 surveys reviewed were rejected in part due to the datum tie requirements[9]
- 12% of the AC-18 reviews took over 45 days to complete

A large unexplained jump in the number of downloads from FAA came in FY 2018 and held in FY 2019 (Table 4).

Table 4. ASP AGIS Data Downloads, FY2015-FY 2019

Deliverable	FY2015	FY2016	FY2017	FY2018	FY2019
AC-18B Survey Data	266	281	282	354	353
AC-17 Imagery Data	176	173	172	228	228
AC-16 Geodetic Control Plan	32	43	19	21	21
AC-16 Geodetic Control Data	34	61	32	28	28
Total	**508**	**538**	**505**	**631**	**630**

Limited data is available on ASP's other activities. The numbers of Primary Airport Control Stations (PACS) and Secondary Airport Control Stations (SACS) validated and entered into the National Spatial Reference System (NSRS) in recent years are shown in Table.[10] FAA no longer requires that contractors establish PACs and SACs, but some continue to do so when needed.

Table 5. Number of PACS and SACS Survey Points Entered into the NSRS by NGS

Fiscal Year	Projects	Points
2017	13	39
2018	18	54
2019	7	21

Note: Estimated by NGS at three times the number of projects.

The aerial photography and support files that NGS provides to the FAA Airways Facilities Tower Integration Laboratory (AFTIL) are used in the FAA models for control tower siting to take into account runway ends, runway heights and obstructions. FAA requirements for site location, tower height and cab orientation are applied to proposed new towers, replacement of existing towers and modernization

[9] The datum tie information is often available but omitted from the survey submission in these cases.
[10] The falloff in FY 2019 occurred because FAA issued a new Advisory Circular 150/5300-18B which clarified that contractors were no longer required to establish PACS and SACS.

of control towers where the overall height of the structure is changed. The models are also used in simulations for training air traffic controllers. These functions are important to safety and they can provide benefits to many controllers and flights long into the future.

FAA uses two models, a quick look to see if a full siting analysis is needed – which is done about 12 times a year, and a full siting which is done 2 or 3 times a year. The main use of ASP data is in the full siting. ASP provides data collected in a format which can be used for 3D virtual reality.

Program Beneficiaries and Nature of Benefits

The NGS Aeronautical Survey program enables FAA decisions that provide extensive benefits throughout the economy and society. Many of these are enumerated in the following material and data on the scale of some sectors that benefit is then indicated.

Beneficiaries of ASP activities range from airports, aviation and their suppliers to cargo shippers and passengers, to industries, the economy, and communities. Sources and nature of benefits are shown for each of 11 sectors in Table 6.

Table 6. ASP Beneficiaries and Sources and Nature of Benefits (1 of 2)

Sector	Source of Benefits	Nature of Benefits
Airports	Approval of runway use Shorter landing patterns More all-weather flying with increased authorization of instrument flight procedures	Better scheduling and availability Reduced need for more extensive types of airport expansion Lower cost and increased business and jobs induced by lower costs Assurance of safety with enabled authorizations
Aviation (public and private)	Increased availability and choice of runways and destinations due to greater availability of runways and more all-weather flying with increased authorization of instrument flight procedures Ability to schedule more flights with shorter landing patterns and less circling	More flights; less need for buffers in schedules Higher capacity utilization with more convenient flights and fewer missed connections Lower cost, including less use of fuel and fewer aircraft Less congestion in the skies and in airports Assurance of safety with enabled authorizations Expansion of activity and jobs induced by lower costs Greater access to more profitable destinations More convenience and choice for private aircraft Increased availability of smaller airports to take overflow from major airports and to provide alternatives in an emergency Less pollution from reduced use of fuel
Suppliers to airports and aviation	Increased demand with greater airport and aviation activity Greater efficiency in delivering supplies to airports and airlines	Lower cost More revenue and jobs
Cargo shippers	Fewer delays and greater predictability of deliveries Better intermodal connections	Lower cost with fewer delays Increased sales and jobs for shippers with lower costs More convenience with faster and more predictable delivery of consumer orders

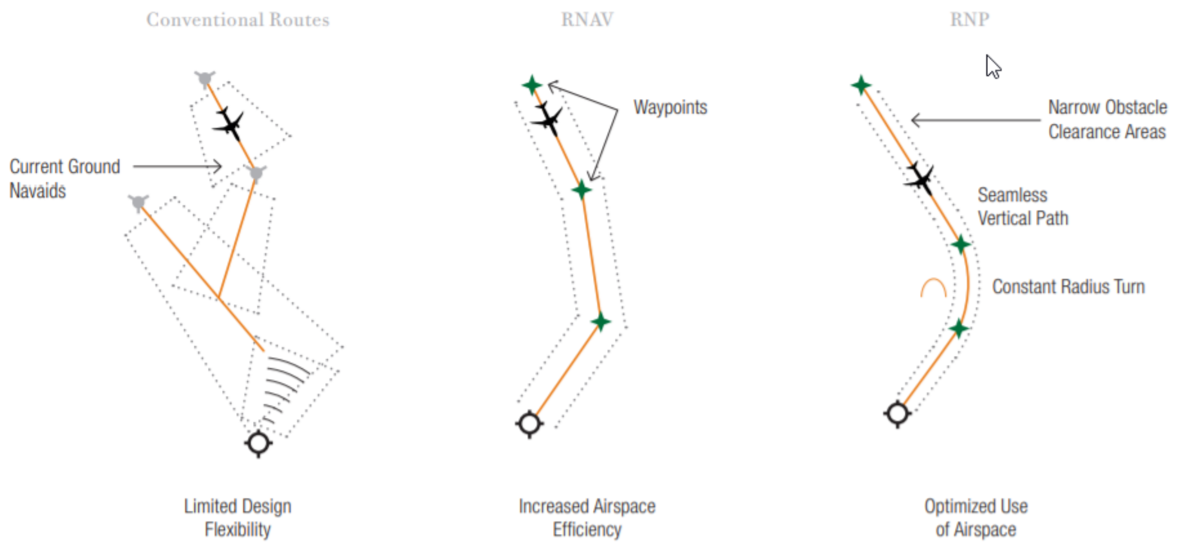
Table 6. ASP Beneficiaries and Sources and Nature of Benefits (2 of 2)

Sector	Source of Benefits	Nature of Benefits
Manufacturers and distributors	Fewer delays and more efficient production and distribution	Lower costs and less need for standby capacity Improved international competitiveness of U.S. companies and industries
Travel and tourism industry	Fewer delays and greater predictability of events and arrival of participants and personnel	Greater choices of destinations Increased travel with greater reliability More efficient planning of arrivals and departures of customers, personnel, and supplies Better connections among flights, cruise ships and other modes of travel requiring less customer assistance
Other using industries	More efficient and predictable availability of traveling employees and shipped supplies	Lower costs and better workflow Increased demand and jobs from lower costs Greater access to domestic and international markets
Passengers	More and more regular flights and more predictable and on-time flights	Greater choice of flights and destinations Reduced travel time and inconvenience, including fewer flight delays and missed connections Lower air fares Greater assurance of safety Better connections between flights and cruise ships and other modes of travel Increased interaction with friends and relatives
Consumers of goods and services other than travel and tourism	More regular and faster movement of products, including capital goods, and improved movement of business personnel	Greater and more predictable availability of goods and services Lower cost
Communities	More reliable and predictable flights and more destinations Greater airport activity	Less noise with shorter landing patterns and less circling More efficient businesses Economic expansion, including attracting and growing firms and industries More vibrant communities interacting more extensively with others
Economy	Expansion of airports, aviation and affected industries and consumers	Economic benefits of increased connectedness among businesses and communities

Use of Instrument Flight Rules

Airplane and airport operations are more efficient and users obtain greater benefits when airports are qualified for use of instrument flight rules (IFR) or for Performance Based Navigation (PBN) which includes the use of instrument flight rules. Figure 6 illustrates landing paths under conventional flight rules, with Area Navigation (RNAV) which allows an aircraft to choose any course within a network of navigation beacons, and with Required Navigation Performance (RNP) which requires the operation of aircraft along a precise flight path with a high level of accuracy and integrity.

Figure 6. Conventional Routes Compared to PBN-Based Routes



Source: David Nakamura, and William Royce, *Operational Benefits of Performance-Based Navigation*, Aero Magazine, Boeing, Q2, 2008,p.14 http://www.boeing.com/commercial/aeromagazine/articles/qtr_2_08/AERO_Q208_article3.pdf

Benefits of using instrument flight rules are described in an addendum to this chapter.

Flight rules and performance standards which valid obstruction surveys enable can have important impacts on safety as well efficiency of airports, airlines and those that depend on them. Some aspects of safety are considered in Appendix C.

Sizes of Benefitting Sectors

Airports and Airlines

The U.S. had 19,339 civil public and private use airports in 2018 (Table 7). The 5,090 public use airports handled the great majority of traffic.

Table 7. U.S. Airports, 2018	
Type	**Number**
Civil public use airports	5,090
Civil public use Part 139	*523*
Civil public use non-Part 139	*4,567*
Civil private use airports	14,249
All civil airports	**19,339**
Military airports	278
All airports	19,624

Note: Part 139 is a voluntary certification that certain standards are met.
Source: FAA Office of Airports as reported in FAA *Administrator's Fact Book*, June 2019
https://www.faa.gov/news/media/2019_Administrators_Fact_Book.pdf

Scheduled airlines made more than 10 million flights and carried over 1 billion passengers in 2018 (Table 8).

Table 8. Scheduled System-Wide (Domestic and International) Airline Travel on U.S. and Foreign Airlines, 2018	
Passengers (in millions)	1,011.50
Flights (in thousands)	10,012.30
Revenue Passenger Miles (in billions)	1,511.70
Available Seat-Miles (in billions)	1,822.00
Load Factor	83
Flight Stage Length	995.8
Passenger Trip Length	1,494.60

Source: U.S. Department of Transportation, Bureau of Transportation Statistics
https://www.bts.dot.gov/newsroom/2018-traffic-data-us-airlines-and-foreign-airlines-us-flights

Eight out of 10 passenger enplanements were for domestic flights on U.S. carriers (Table 9).

Table 9. Number of Passenger Enplanements on U.S. and Foreign Carrier's U.S. Flights, 2018 (millions)	
U.S. Carrier	
Domestic	777.9
International	111.1
Foreign Carrier to and from U.S.	122.5
Total	**1,001.5**
Source: U.S. Department of Transportation, Bureau of Transportation Statistics https://www.bts.dot.gov/newsroom/2018-traffic-data-us-airlines-and-foreign-airlines-us-flights	

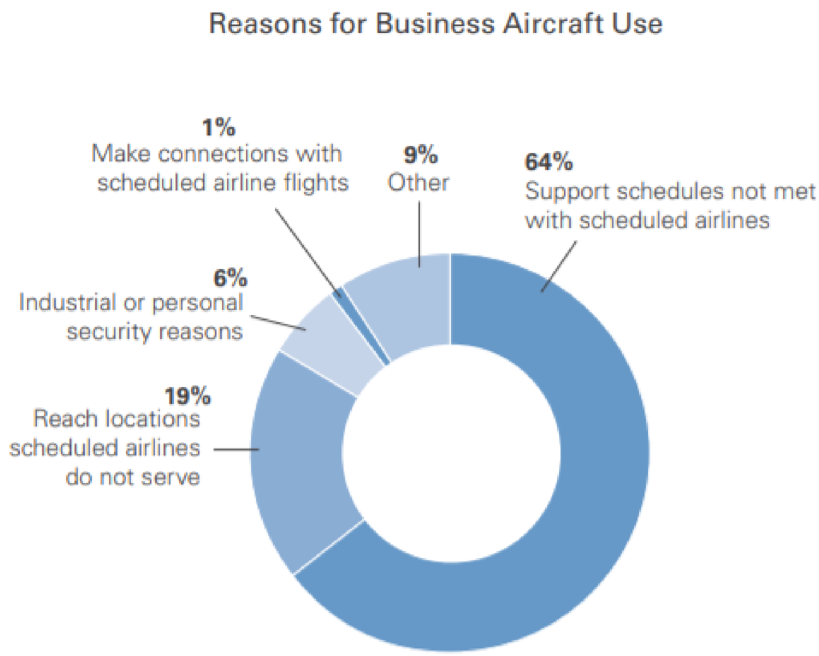
The airline industry flew 16 million ton-miles of freight domestically and 64 million ton-miles internationally (Table 10).

Table 10. Revenue Ton-Miles of Freight and Mail Carried by U.S. Airlines, 2018 (millions)	
Domestic	15,969
International	63,835
Total	**79,803**
Note: A ton-mile is transportation of one ton for a mile. Source: U.S. Department of Transportation, Bureau of Transportation Statistics https://www.transtats.bts.gov/freight.asp?pn=0&display=data2	

Business Aviation

According to the National Business Aviation Association, 64% percent of business aircraft use is to support schedules that are not met with scheduled airlines. Another 19% is to reach locations scheduled airlines do not serve (Figure 7).

Figure 7



Source: National Business Aviation Association, *Fact Book*, p.9, from Harris Interactive Survey, October 2009 https://nbaa.org/wp-content/uploads/2018/01/business-aviation-fact-book.pdf

FAA determined that the overall economic impact of general aviation, measured as a percent of commercial aviation activity, was as follows in 2014:[11]

Airline operations:	11.9%
Aircraft manufacturing	39.1%
Visitor expenditures	1.5%

The National Business Aviation Association reported that:[12]

> "Business aviation serves 10 times the number of U.S. airports (more than 5,000) served by commercial airlines (about 500)….
>
> The vast majority of the U.S. companies that utilize business aircraft – 85 percent – are small and mid-size businesses, many of which are based in the dozens of communities across the country where the airlines have reduced or eliminated service….

[11] U.S. Department of Transportation, Federal Aviation Administration, *The Economic Impact of Civil Aviation on the U.S. Economy*, November 2016, p.28 http://www.faa.gov/about/office_org/headquarters_offices/ato/media/2008_Economic_Impact_Report_web.pdf

[12] National Business Aviation Association, *Fact Book*, pages 4 and 5 https://nbaa.org/wp-content/uploads/2018/01/business-aviation-fact-book.pdf

Several studies have shown that the productivity and efficiency gains from business aviation translate into tangible and quantifiable benefits for companies, shareholders and the national economy."

Value Added in Airports, Airlines, Aviation Manufacturing and Travel

Value added by airport operations as estimated by the FAA was $27.6 billion in 2006, while airline, general aviation, and air courier operations directly contributed value of $177.4 billion to the economy. Value added in manufacturing of aircraft and parts and avionics research totaled $130.4 billion. Aviation visitor expenditures contributed $369.6 billion. Components of these expenditures are shown in Table 11. Information on jobs and broader economic contributions is provided in Appendix A.

Table 11. Value of Output in Aviation and Some Impacted Sectors, 2016
(billions of dollars)

Sector	**Primary Output** (value added)
Airline operations	131.9
Airport operations	27.6
Civilian aircraft manufacturing	58.0
Civilian aircraft engine and engine parts manufacturing	8.0
Civilian other aircraft engine parts and equipment manufacturing	29.0
Civilian avionics manufacturing	10.5
Civilian research and development	13.3
General aviation operations	21.9
General aviation aircraft manufacturing	11.6
Air couriers	24.6
Subtotal – Direct Impact	336.4
Airline visitor expenditures	357.8
General aviation visitor expenditures	4.7
Travel arrangements	7.1
Subtotal - Indirect	369.6
Total Direct Impact	**706.1**

Source: U.S. Department of Transportation, Federal Aviation Administration, *The Economic Impact of Civil Aviation on the U.S. Economy*, January 2020, Tables 3 and 4
https://www.faa.gov/about/plans_reports/media/2020_jan_economic_impact_report.pdf

Addendum: Benefits of Using Instrument Flight Rules

Using instrument flight rules (IFR) instead of visual flight rules (VFR) provides aircraft with precision vertical and horizontal navigation guidance during approach and landing. The elements of ILS are depicted in Appendix D. IFR also is incorporates Area Navigation (RNAV) which provides flight procedures for properly equipped aircraft and Required Navigation Performance (RNP) which defines the level of performance required for a specific block of airspace.[13]

Without necessary instruments, aircraft can be unable to operate in severe weather, must use less efficient landing routes and are more likely to experience missed approaches or be diverted to another airport.[14] Use of these instruments requires availability of GPS with signals enhanced by the Wide Area Augmentation System.

Leveson described several estimates of benefits associated with use of GPS in aviation in a 2015 study of GPS benefits for the National Executive Committee for Space-Based Positioning, Navigation and Timing:[15]

> "The FAA NextGen Systems Analysis Office estimated in 2011 that GPS provided at least $200 million in efficiency benefits for aviation each year.[16]
>
> The 2009 WAAS Business Case Analysis Report found economic benefits to users compared to instrument landing systems (ILS) of $46 million, of which $39 million was savings in passenger time.[17] Aircraft operator cost savings were not included. The projection for 2013 was $122 million.
>
> The NextGen Systems Analysis Office prepared new estimates for 2013 for this [the 2015] study with a contribution from MITRE. Benefits came primarily from flight efficiency (time and fuel) with Performance-Based Navigation (PBN) and reduced delays in taking off to airports with low visibility made possible by WAAS. The analysis attributed benefits of $198 million to systems using GPS including WAAS."

A study by MITRE about 15 years ago quantified the benefits of using RNP procedures in the U.S.[18] The study's simulations for 12 airports showed that RNP Parallel Approach with Transition (RPAT) increased

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[13] David Nakamura, and William Royce, *Operational Benefits of Performance-Based Navigation*, Aero Magazine, Boeing, Q2, 2008 http://www.boeing.com/commercial/aeromagazine/articles/qtr_2_08/AERO_Q208_article3.pdf

[14] Andy Pasztor, "FAA Sets New Rules at Busiest Airports," *Wall Street Journal*, November 24, 2014, p.A2

[15] Irving Leveson, *GPS Civilian Economic Value to the U.S., Interim Report*, prepared for the National Executive Committee for Space-Based Positioning, Navigation and Timing, August 31, 2015, pp.54-55 http://www.performance.noaa.gov/wp-content/uploads/2015-08-31-Phase-1-Report-on-GPS-Economic-Value.pdf

[16] Joel Szabat, "Letter to Karl B. Nebbia, Associate Administrator, National Telecommunications and Information Administration, on the impact of the LightSquared Concept of Operations, and Appendices," U.S. Department of Transportation, Office of the Secretary, July 21, 2011 http://science.house.gov/sites/republicans.science.house.gov/files/documents/Letters/2011%2007%2021%20DOT%20LSQ%20Impact%20Assessment.pdf

[17] Federal Aviation Administration, *Wide Area Augmentation System (WAAS) Business Case Analysis Report*, Exhibit 300, Program Baseline Attachment 2 for WAAS Service-Level Mission Need Statement #0050, August 2009.

[18] Devlin, Christopher, *et*, *al*., "Applications and Benefits of RNP Approaches in the United States National Airspace System," The MITRE Corporation, n.d. https://www.mitre.org/sites/default/files/pdf/05_1141.pdf

arrival capacity in single runway operations in most of the airports examined, and with dual runway operations in three airports, arrival capacity increased by 16%-59%. Airport delay savings were multiplied by costs for each airport to obtain dollar values. The total benefit across the 12 airports was $11.1 million in 2003. This does not include costs to pilots, airlines, passengers, or cargo handlers and shippers, or multiplied effects on the economy.

IV. Methods of Estimating Socio-Economic Benefits

Conceptual Considerations

> Benefits of programs depend on the comparison on actual outcomes with those that would be expected in the absence of the programs.

Benefits of programs can take many forms, including increases in output, added services or service enhancements, decreases in costs, increased safety and security and improvements in the environment. In the case of aviation, benefits can derive from more efficient flights, additional routes, efficiencies in the national air space and other outcomes that can significantly impact passengers, cargo, airports, airlines, crew, and local communities and industries, and have regional, national, and international impacts.

Benefits of programs depend on the comparison of actual outcomes with those that would be expected in the absence of the programs. Outcomes in the absence of a program can be described by counterfactual scenarios indicating alternative developments or conditions if the program were not in place. Multiple scenarios can be posited if there is more than one type of alternative evolution of interest.

Outcomes may be gauged by before and after comparisons if a program is introduced or undergoes substantial changes. Where appropriate data exists it may be possible to infer impacts by statistically holding constant other influences.

Ideally one would want to estimate each of the benefits for each of the benefitting sectors. Determining each type of benefit for each sector can require information in very great detail and the existence of individual types of impacts that are large enough to emerge in statistical analyses for separation of program effects. Enumeration of underlying benefit measures is useful when that is not possible because it helps in understanding the benefits that may instead be subsumed in broader measures.

Conceptual Types and Measures of Benefits Illustrate What is Subsumed in Broader Measures

Conceptual types of benefits and measures that in principle could apply to each of the sectors impacted by developments in aviation are enumerated in Table 12. For a program that is extremely small with potentially wide-ranging impacts such as the NGS Aeronautical Survey Program, use of such detailed measures would necessitate a huge effort, and even then require extensive assumptions about the contribution of the program vs. the many and often powerful other factors that influence the components. In the absence of the ability to make such detailed estimates of impacts it can be necessary to make inferences from broader effects of which benefits of the program are a part.

Table 12. Conceptual Measures of Benefits of the Aeronautical Survey Program (1 of 3)

Sector	Benefit	Measure
Airports	Better scheduling and availability	Changes in number of flights and destinations and on time performance; reduced cost
	Reduced need for more expensive types of airport expansion	Avoided costs; reduced disruption; value of faster availability of added capacity
	Increased business and jobs	Associated changes in airport revenue and employment
	Assurance of safety with enabled authorizations	Views of passengers
Aviation (public and private)	More flights; less need for buffers in schedules	Number of additional flights; changes in flight schedule times
	Higher capacity utilization with more convenient flights and fewer missed connections	Changes in airline capacity utilization; number of missed connections and their loads
	Lower cost, including less use of fuel and fewer aircraft	Changes in airline operations costs by type
	Less congestion in the skies and in airports	Frequency of aircraft waiting to land; time spent circling
	Assurance of safety with enabled authorizations	Views of pilots and air traffic controllers
	Expansion of activity and jobs induced by lower costs	Change in passenger and cargo volumes; number of flights by type; numbers and types of airline jobs
	Greater access to more profitable destinations	New routes and added flights; profitability of flights to each route
	More convenience and choice for private aircraft	Number of landing slots in desirable locations
	Increased availability of smaller airports to take overflow from major airports and to provide alternatives in an emergency	Number of additional airports and runways and their capacity
	Less pollution from reduced use of fuel	Changes in fuel use from the switch to more direct flights and estimates of associated air pollution
Suppliers to airports and aviation	Lower cost	Change in operating costs of suppliers; changes in costs of goods and services to airports
	More revenue and jobs	Changes in supplier revenue and employment

Table 12. Conceptual Measures of Benefits of the Aeronautical Survey Program (2 of 3)		
Sector	**Benefit**	**Measure**
Cargo shippers	Lower cost with fewer delays	Change in shipping costs by type of freight; change in number and length of flight delays and associated reduction in shipping costs; changes in freight prices by type, size and weight
	Increased sales and jobs for shippers with lower costs	Change in cargo shipper revenue and change in their employment
	More convenience with faster and more predictable delivery of consumer orders	Changes in delivery speeds and regularity; value to consumers of faster and more predictable delivery
Manufacturers and distributors	Lower costs and less need for standby capacity	Greater ability to use broader supply chains and just-in-time methods
	Improved international competitiveness of U.S. companies and industries	Change in international exports of companies and industries in areas with airport improvements; reductions of international imports in communities with increased airport runway capacity
Travel and tourism industry	Greater choices of destinations	Greater customer satisfaction; increased travel; Lower costs with increased occupancy rates
	Increased travel with greater reliability	Lower costs with increased occupancy rates
	More efficient planning of arrivals and departures of customers, personnel, and supplies	Lower costs with increased occupancy rates: Fewer avoided or cancelled trips and less cost of obtaining refunds and credits
	Better connections among flights, cruise ships and other modes of travel requiring less customer assistance	Greater customer satisfaction; reduced travel time; increased travel
Other using industries	Lower costs and better workflow	Changes in costs of production and distribution and product prices
	Increased demand and jobs from lower costs	Changes in revenue; changes in employment
	Greater access to domestic and international markets	Increased use of flights to new destinations; changes in volumes to previously less accessible destinations

Table 12. Conceptual Measures of Benefits of the Aeronautical Survey Program (3 of 3)

Sector	Benefit	Measure
Passengers	Greater choice of flights and destinations	Changes in numbers of flights and destinations where runways have been added or improved
	Reduced travel time and inconvenience, including fewer flight delays and missed connections	Changes in travel time; numbers of missed connections; lost time and added costs to passengers from missed connections
	Lower air fares	Changes in air fares on affected routes
	Greater assurance of safety	Passenger perceptions
	Better connections between flights and cruise ships and other modes of travel	Consumer surveys of missed connections and their consequences
	Increased interaction with friends and relatives	Surveys of reasons for additional travel and/or changed travel patterns
Consumers of goods and services other than travel and tourism	Greater and more predictable availability of goods and services	Surveys of changes in supplies of goods and services in affected locations
	Lower cost	Changes of prices of goods and services in affected locations
Communities	Less noise with shorter landing patterns and less circling	Changes in noise frequency by intensity associated with traffic at affected runways
	More efficient businesses	Improved competitiveness and sales among business using affected airports and/or runways
	Economic expansion, including attracting and growing firms and industries	Increased business revenue and incomes, personal incomes and employment
	More vibrant communities interacting more extensively with others	Increased frequency of travel to areas with new or additional flights Economic performance in destination communities
Economy	Economic benefits of increased connectedness among businesses and communities	Increased economic activity, increased efficiency, jobs and tax revenue in companies, communities and local economies that are affected indirectly as well as those that are affected directly

Substitution among airports, aircraft, flight patterns, and modes of transportation could potentially reduce losses from FAA restrictions. However, alternatives might be more costly and/or involve delays and possibilities for substitution could be limited during the time it takes for a survey to be approved.

A number of safety and environmental effects are possible in addition to economic impacts. If runways and other facilities were not used because surveys had not been conducted there would be fewer flights which would result in more favorable aggregate safety data. It is not clear how or how much safety measures per flight would be affected.

Environmental impacts from restrictions put in place where obstruction surveys were incomplete or deficient could come from greater use of fuel per flight with less efficient landings and takeoffs and longer flight paths. However, with restrictions in effect, fewer flights would take place as a result of higher costs and the inability of some planes to land and take off in bad weather, which would result in less total use of fuel.

Noise would be greater under restrictions with additional time in the air due to longer landing paths, more circling and more missed approaches.

Estimating Benefits of ASP

The analysis primarily involves consideration of the implications of using or not using airport obstruction surveys based on whether they are properly and completely conducted and documented and appropriately tied to the NSRS. The focus is on civil aviation impacts in the U.S., including both commercial and non-commercial flights and passenger and cargo flights. The study does not consider costs of the program or costs to producers or users of the information.

Economic benefits of ASP reviews of survey plans and surveys derive from authorizations affecting use of the airspace and runways and the ability to have more flights to more destinations. The program may enable approval for use of instrument landing systems for all-weather flying, resulting in shorter flights, more destinations, and fewer delays and flight cancellations. It may allow more efficient landing paths with absence of height buffers or stepdown landing requirements and/or less circling, fewer missed approaches and greater takeoff weights.

The contribution of the ASP program to safety depends on differences in safety outcomes from what would occur if the program did not exist. When safety is addressed by the FAA in setting flight procedures and restrictions, the resulting improvements in safety are not observed. What may potentially be observed is the increased output, improved service, or cost reduction for airlines, airports, passengers, and cargo when those restrictions are no longer required. This is reflected in the conceptual measures in Table 12.

When safety is addressed by the FAA in setting flight procedures and restrictions, the resulting improvements in safety are not observed. What may potentially be observed is the increased output, improved service, or cost reduction for airlines, airports, passengers, and cargo when those restrictions are no longer required.

In the absence of data to measure outcomes at a detailed level, in order to determine the contribution of the program, in some cases it is necessary to allocate a portion of broader benefits to the program's activities. This is the case for 4 of the 5 component estimates. However, such an allocation is not necessary for the 5th component which accounts for the great bulk of the combined estimate.

Only runways and other part of airports undergoing surveys in a particular year contribute to benefits in that year. Consequently, the estimates must take into account the portion of runways that have obstruction survey plans and surveys in that one year.[19]

Benefit Analysis Approach and Methods

Approach

Benefits of the NGS Aeronautical Survey Program are assessed under two alternative scenarios:

1) Loss of incremental value
2) Partial loss of incremental value

In the "loss of incremental value" scenario the loss comes because the ASP program does not exist. In "partial loss of incremental value" scenario the work is done in other settings that are less effective and/or more costly.[20] Two alternative arrangements to which partial losses may be attributed are described. For purposes of illustration, the loss under the partial loss scenario is assumed to be 10%-20% of the loss under the full loss scenario.

> The approach, necessitated by the availability of information, relies on secondary sources of data, attributing portions of benefits of broader measures to ASP.

Estimates of benefits in 2019 are derived by adaptation of broader measures from various studies using differing data and methods. The approach, necessitated by the availability of information, relies on several studies and secondary sources of data, attributing portions of benefits of broader measures to ASP. The allocations are based on the share of runways reviewed by ASP in a year and indications or judgements of the share of benefits of those activities attributable to ASP. Long term benefits are examined by discounting future benefits streams assuming continuation of the program at the same level.

Estimation of benefits of ASP's main reviews of plans and surveys is based on examination of 5 components:

1. Analysis of benefits of the Wide Area Augmentation System (WAAS) which enhances the GPS signal that is relied on for ILS
2. Fuel cost savings with continuous descent arrivals (CDA)
3. Reduced cost of flight delays due to weather with ILS
4. Value of passenger time saved with reduced flight delays due to airport improvements

[19] ASP program benefits continue in subsequent years until the next survey is made. In practice, however, if a survey is not adequate, the deficiencies would either be rectified by the same contractor or another contractor would have to be selected. This might involve a delay and loss of benefits of up to only a couple of years.
[20] Before and after comparisons of changes with introduction of the ASP program would not provide evidence comparable to the present situation even if data were available. Previously ASP did the surveys itself. Also, for a time FAA dealt with three or four large contractors who came to NGS for training, so there were fewer problems than in the present situation which involves many more and some less experienced contractors.

5. Transportation Research Board estimates of the value of changes in connectivity and activity,[21] together with airport-specific FAA data on the sizes of airport capacity expansions

The ranges of the component measures are combined into an overall range of benefits.

The value of NGS entering airport survey points (PACS and SACS) into the NSRS is considered in discussion of the number of points in perspective to the size and needs of the NSRS. The contribution of the program to siting airport traffic control towers and air traffic controller training is discussed in relation to FAA requirements for airport control tower siting and information obtained by interviewing providers and users of the information about frequency and use of the NGS information. The benefits of these activities are not quantified.

Methods of Benefit Estimation

The FAA uses an established methodology for cost-benefit analyses of airport improvement projects which delineates possible benefits and spells out methods for their valuation.[22] The study's estimates take account of these procedures.[23]

A wide range of sources and types of information is used. Interviews contribute to understanding of possible alternatives to the program and key influences.

Uncertainty is indicated by use of alternative overall scenarios and by ranges to reflect uncertainty in individual estimates and illustrative values. Statistical measures of uncertainty in the TRB econometric estimates which are a major part of the overall estimates are taken into account.

Order of magnitude economic multiplier effects are used to incorporate direct, indirect, and induced effects on the economy. Indirect effects are impacts on demand for goods and services of supporting companies and industries. Induced effects include both impacts on demand for products and on process innovation in impacted industries and the broader economy. Multipliers from other studies, often based on elaborate input/output models and econometric models of the economy are adapted using conservative values.

Benefits are extrapolated for 10 years. Present discounted values of illustrative future benefits are calculated using the 7% value required by OMB. Implications of alternative discount rates are shown.

[21] Transportation Research Board, Airport Cooperative Research Program, *The Role of U.S. Airports in the National Economy*, ACRP Report 132, 2013 https://www.nap.edu/catalog/22146/the-role-of-us-airports-in-the-national-economy

[22] https://www.faa.gov/airports/aip/bc_analysis/

[23] When benefits are much larger than a program's costs, it is appropriate and customary to show the "net gain" rather than the ratio of benefits to costs. However, often it is not useful to deduct the cost of the program in a formal net gain calculation when the present value of benefits is very much larger than cost, rather than to show the cost separately.

Jobs Supported by the Program

Impacts on jobs are estimated based on the relationship of value added to jobs for sectors which depend directly on the national airspace using employment multipliers that take into account implications of effects on the broader economy.

Effects on employment depend on the way the improvements are used. Improvements in efficiency can allow more to be produced at the same cost or the same to be produced at lower cost, possibly with fewer jobs. Expansion of activities without productivity gains draws resources from other sectors. Available measures of employment multipliers do not flexibly allow for a range of effects.

V. Preliminary Estimates of the Value of the Aeronautical Survey Program

Counterfactual Scenarios

The first step in estimating the value of the ASP program is to develop counterfactual scenarios indicating what would be expected if the program did not exist. These scenarios reflect long run adjustments to the arrangements and do not consider costs during a transition. Two scenarios for estimating the value of ASP review and validation of airport obstruction surveys are considered:

1) Full Loss of incremental value
2) Partial loss of incremental value

In the full loss scenario the value of NGS ASP review and validation of plans and surveys is lost because the surveys are not utilized. That is because FAA does not conduct its Airport Improvement Program without any survey capability.

In the partial loss scenario the program is under alternative arrangements that are assumed to involve less capability, timeliness, and/or higher cost. Two arrangements that place the airport obstruction survey review functions in other settings, are illustrated.

Full Loss Scenario 1. ASP Review vs. No Review

NGS is independent, focuses on safety aspects of airport obstruction surveys, validates the data for FAA, focuses the requisite skills, draws on concentrated expertise throughout NGS, maintains some databases that FAA does not maintain, adds information to surveys including data from NOS' own surveys, converts the data to UDDF format that all FAA offices can use, provides feedback to contractors that can improve their future submissions and reduce their costs as well as those of the ASP program, incorporates geodetic data into the NSRS and coordinates with NGS efforts to inform and assist NSRS users. ASP also makes recommendations for the development of FAA survey standards, provides data for airport control tower siting analysis which supports siting and air traffic controller training and is prepared to conduct requested survey for FAA such as a survey to establish an accuracy standard for airport layout plans.

Without ASP's systematic efforts to assure the survey plans and surveys properly and fully address issues, projects involving substantial economic resources and benefits could be delayed or blocked. FAA would have to place restrictions on approaches and takeoffs that slow traffic and add costs. Increases in all-weather flying would be held back.[24] If ASP didn't exist and no alternative was employed, related functions that ASP provides also would not be performed.

[24] If some of the unvalidated surveys were used there could be significant consequences for safety.

Partial Loss Scenario 2, Variant 1: Review by a private contractor

Use of a private contractor could result in higher costs than NGS reviews and lack the same degree of staff continuity. The contractor might not have as much flexibility as NGS in drawing on other staff at the times needed, especially considering the special demands of understanding FAA requirements and airport surveys. While a large contractor might have extensive technical resources to draw on, even staff that are knowledgeable in conducting airport surveys may be spread among locations and have to split responsibilities with other activities having fluctuating demands. Costs could be higher than at NGS because of the cost structure that is applied to its other activities.

Partial Loss Scenario 2, Variant 2: Review by FAA

FAA might not have the requisite GIS and geodesy skills in house even after a transition because of less of a focus on the work and less room for advancement in the field. In view of the great many detailed requirements of the reviews, less attention might be paid to the safety aspects than is paid by NGS. FAA staff might be less focused on reviewing obstruction surveys than NGS if subject to the press of other duties, possibly leading to less honing of the required skills and less thorough reviews. Some functions that the ASP program performs other than reviewing survey plans and surveys might not be fulfilled, including adding data to the surveys from databases that FAA does not now maintain and correcting and cataloging obstruction data. Moreover, without the independence of NGS, FAA reviews might not be entirely free from pressures from sources in or out of government.[25]

Economic Benefit Estimates

Component Estimates

Preliminary order of magnitude estimates of the loss of benefits of ASP's principal review and validation functions in 2019 are made for five overlapping components using diverse methods and data sources. The fifth component of the estimates which accounts for the majority of benefits applies directly to ASP. For the remaining components, portions of benefits of broader measures are allocated to ASP based on the share of runways reviewed by ASP in a year and indications or judgements of the share of benefits of those activities attributable to ASP. The component estimates are presented as illustrative ranges of possible magnitudes.

The components of the

1. Savings from use of WAAS
2. Fuel Cost Savings with continuous descent arrivals (CDA)
3. Reduced cost of flight delays due to weather with ILS

[25]AOPA maintains that control towers would have higher costs and less focus and flexibility if FAA staffed them rather than contracting out. If correct, this might be indicative of outcomes if FAA conducted the airport obstruction survey reviews itself. For example, AOPA, "Letter to The Honorable Nita M. Lowey, Chairwoman, House Appropriations Committee," February 19, 2020 https://download.aopa.org/advocacy/2020/FY21associationcontracttowerappropsletter.pdf?_ga=2.241763842.1429740456.1583106311-528783971 .1579038967

4. Value of passenger time saved with reduced flight delays due to airport improvements
5. Benefits of increased airport connectivity

Each of the estimates is discussed in turn.

1. Savings from Use of WAAS in Aviation

The Wide Area Augmentation System (WAAS) increases the accuracy and reliability of GPS signals through the use of satellites and ground systems. Aircraft with WAAS augmentation are authorized to fly using Area Navigation (RNAV) under Instrument Flight Rules (IFR) without reliance on ground-based navigation aids. Airport GIS surveys are needed before IFR can be approved.

The Airline Owners and Pilots Association (AOPA) states that:

> "The FAA is publishing WAAS-enabled Localizer Performance with Vertical guidance (LPV) approaches to general aviation airports. They are frequently providing minimums of 200 feet and one-half mile…. The LPV approaches provide unprecedented access to general aviation airports, at a fraction of the cost of traditional ILS approaches. In 2016, there were more than 90,000 aircraft equipped with WAAS and capable of flying any of the nearly 4,000 LPV procedures published."[26]

An estimate of benefits of WAAS to aviation of $198 million was made for the year 2013 by the U.S. Department of Transportation NextGen Systems Analysis Office. This estimate, which is prior to significant use of NextGen, is especially useful because it focuses on the advantages of WAAS in flying in bad weather.[27] The ability of aircraft to land and take off in severe weather requires either WAAS or a Category I Instrument Landing System (ILS). In either case, ILS is required to determine the height of the glidepath and airport obstruction surveys are required for authorization to use ILS.

The DoT estimate of WAAS benefits is updated by the growth in value added in aviation.[28] This produces a value of $308.6 million in 2019. Actual growth in benefits could have been larger that this with improvements in GPS and WAAS.[29]

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[26] http://aopa.org/advocacy/advocacy-briefs/air-traffic-services-brief-wide-area-augmentation-system-waas

[27] Irving Leveson, *GPS Civilian Economic Value to the U.S., Interim Report*, prepared for the National Executive Committee for Space-Based Positioning, Navigation and Timing, August 31, 2015, pp.54-55 http://www.performance.noaa.gov/wp-content/uploads/2015-08-31-Phase-1-Report-on-GPS-Economic-Value.pdf The estimate takes into account the extent of use of WAAS but details have not been made available.

[28] Value added by industry is the industry composition of GDP.

[29] Benefits of flight augmentation with WAAS will further increase in the future as WAAS shifts to dual frequency operation to take advantage of the new GPS L5 signal, the European Galileo system's E5 signal and potentially use of the Chinese Beidou satellite system.

An allocation is made of the estimate of WAAS benefits that covers all 5,090 paved U.S. runways to include only those undergoing ASP reviews in a year. This number is judged to be 100-150 runways or 2%-3% of the total. Taking 2%-3% of $308.6 million yields a contribution of ASP to WAAS benefits in 2019 of $6.2-$12.3 million.

2. Fuel Savings with Continuous Descent Arrivals

Karen Van Dyke of the Volpe National Transportation Center recently reported some of the savings from "continuous descent arrivals" (CDA) which fly a continuous descent path rather than traditional step downs or intermediate flight operations.[30] These flights use Area Navigation (RNAV) with Required Navigation Performance (RNP) which reduces pilot/controller communications and uses Flight Management System (FMS) capabilities to manage energy and reduce cockpit workload. Ms. Van Dyke reported that this provides benefits to airlines of 200-400 lbs. of fuel per arrival and has additional benefits to airports of reduced emissions and noise.[31] Passengers and cargo shippers also may benefit from reduced flight times while airports, airlines, and customers may benefit from the ability to schedule more flights.

Savings per gallon is combined with fuel prices to estimate the total value of savings. At 6.7 lbs. per gallon, 200-400 lbs. of fuel saved translates into 29.9-59.7 gallons. The average jet fuel price was about $1.70 per gallon in the first half of February 2020 – according the Argus U.S. Jet Fuel Index reported by Airlines for America.[32] This places the value of fuel saved at $50.8- $101.7 per arrival that is shifted to continuous descent with RNAV and RNP.

Since use of RNAV and RNP requires use of instrument landing systems, the value per continuous descent arrival is combined with an indication of prevalence of CDA to measure the value of ILS and therefore airport obstruction surveys in those arrivals.

FAA reports that:

> "As of March 26th, 2020 there are 4,052 Wide Area Augmentation System (WAAS) Localizer Performance with Vertical guidance (LPV) approach procedures serving 1,955 airports. 1,187 of

[30] Karen Van Dyke, "GNSS Implementations and Innovations in Aviation," slides, Volpe National Transportation Center, May 26, 2008, slides 31-32 https://www.gps.gov/multimedia/presentations/2008/2008-05-APEC/vandyke-aviation.pdf Also see Yi Cao, *et. Al*., "Evaluation of Fuel Benefits Depending on Continuous Descent Approaches," Purdue University, n.d. https://web.ics.purdue.edu/~dsun/pubs/atcq15.pdf
and Eric P. Dinges, "Determining the Environmental Benefits of Implementing Continuous Descent Arrivals," ATAC Corporation, n.d.
https://www.faa.gov/about/office_org/headquarters_offices/apl/research/science_integrated_modeling/media/Environmental%20Benefits%20of%20Continuous%20Descent%20Arrivals.pdf

[31] See Eric P. Dinges, "Determining the Environmental Benefits of Implementing Continuous Descent Arrivals," ATAC Corporation, n.d.
https://www.faa.gov/about/office_org/headquarters_offices/apl/research/science_integrated_modeling/media/Environmental%20Benefits%20of%20Continuous%20Descent%20Arrivals.pdf

[32] https://www.airlines.org/argus-us-jet-fuel-index/ This is taken as representative of 2019 and may be closer to a long run value than prices in mid-2020.

these airports are Non-ILS airports..”[33]

Subtracting 1,187 from 1,955, the number of ILS airports is 768, 15.1% of the 5,090 public use airports in 2018. Airports using RNAV with LPV tend to be the larger ones with larger aircraft and more flights per airport so the share of flights is expected to be larger.

FAA also indicates that:

> “Currently, there are also 725 Localizer Performance (LP) approach procedures in the U.S. serving 532 airports. 430 of these airports are Non-ILS airports.”[34]

This places the number of airports using LP and ILS at 102.

The 100 largest airports had an average of 83,336 departures in 2017, 93.5% of all commercial aviation passenger flights, based on AeroWeb tabulations.[35] If the average number of passenger departures per large airport is applied to the 102 airports using LP and ILS, it implies that those airports had 8.5 million commercial passenger flights.

In the absence of data on the prevalence of CDA it is necessary to use an indication of possible magnitudes of benefits using an illustrative assumption. If 1%-3% of those flights used continuous descent arrivals in 2019, the number of CDA flights would be 85,000-255,000. *This range is consistent with up to 600 CDA flights per optimized flight procedure.* A wide range is used because of uncertainty about CDA use.

With fuel savings of $50.8-$101.7 per CDA arrival, the value of fuel savings with CDA is $4.3-$25.9 million per year. Since valid airport obstruction surveys are required before instrument landing is authorized, the estimated 2%-3% share of runways with ASP reviews in 2019 is applied to the $4.3-$25.9 million savings, yielding savings with ASP of $86,000-$778,000. The estimate does not include use of CDA in cargo flights, savings in labor and other costs and the reduction in environmental costs.

3. Reduced Cost of Passenger Flight Delays Due to Weather with ILS

A further indication of potential savings with valid airport surveys comes from possible reductions in the costs of weather flight delays. ASP contributes to reducing the cost of flight delays by enabling additional or longer runways and all-weather flying with ILS once various FAA restrictions are no longer needed.

Two prominent studies provide extensive information on the national costs of flight delays. The 2010 NEXTOR total delay impact study estimated the cost of all U.S. passenger air transportation delays in 2007 at $32.9 billion[36] The NEXTOR study delay estimates include $28.9 billion in direct costs and $4.0

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[33] “Satellite Navigation – GPS/WAAS Approaches https://www.faa.gov/about/office_org/headquarters_offices/ato/service_units/techops/navservices/gnss/approaches/

[34] *Idem*.

[35] AeroWeb, “Top 100 U.S. Airports in 2017,” Forecast International, downloaded June 2, 2020 http://www.fi-aeroweb.com/Top-100-US-Airports.html

[36] NEXTOR, *Total Delay Impact Study: A Comprehensive Assessment of the Costs and Impacts of Flight Delay in the United States*, October 2010 http://www.trb.org/Main/Blurbs/164271.aspx

billion in indirect effects on the economy. NEXTOR's calculations includes the addition of buffers to flight schedules. The Congressional Joint Economic Committee 2008 estimated costs of flight delays of $40.7 billion in 2007.[37] This includes freight and military flights. JEC found "roughly $10 billion" of impacts on other industries, with about $30.7 billion in direct costs. Both studies include the value of consumer time. Additional information on costs of flight delays is in Appendix I.

Direct costs from these studies are used in estimation because a multiplier is later applied to benefits of ASP as a whole. The average estimate of direct costs in 2007 across the two studies is $29.8 billion. This is considered an underestimate because NEXTOR doesn't consider non-passenger costs and JEC doesn't include costs of buffers in schedules.

The value is updated to 2019 based on the percentage change in the nominal (not adjusted for inflation) value added in air transportation reported by the U.S. Department of Commerce in its Value Added by Industry series.[38] The ratio of air transportation value added in 2019 to 2007 is 2.075. Multiplying 2.075 by the $29.8 billion average of the cost estimates in 2007 yields direct costs of flight delays in 2019 of $61.8 billion.

As noted, the number of ILS airports is 768, 15.1% of the 5,090 public use airports in 2018.[39] Not all flights in ILS airports use ILS. Delays in flights due to lack of use of ILS could significantly affect non-ILS flights in ILS airports and flights in non-ILS airports as well. The combined effects of these considerations are approximated by using the percentage of ILS airports.

The U.S. Department of Transportation's Bureau of Transportation Statistics (BTS) reports weather delays in three categories. The data covers mainline carriers, branded code share partners, additional operating carriers with a 0.5% share of domestic scheduled passenger service, plus ExpressJet Airlines.

1. Extreme weather includes actual or forecasted conditions that delay or prevent the operation of a flight. Among these conditions are tornadoes, blizzards, and hurricanes. Extreme weather's share of flight delay-minutes varied between 4.0% and 6.9 since 2013, with the highest values during the first three years.
2. A second category called National Aviation System (NAS) includes non-extreme weather and developments such as those related to airport operations, heavy traffic volume and air traffic control. Non-extreme weather accounted for 56.8% of NAS delays in 2019.
3. BTS also makes an allocation based on the first two categories to also include a share for weather from the category "late-arriving aircraft."

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[37] U.S. Congress, Joint Economic Committee Majority Staff, *Your Flight Has Been Delayed Again: Flight Delays Cost Passengers, Airlines, and the U.S. Economy Billions*, Joint Economic Committee, May 2008 https://www.jec.senate.gov/public/index.cfm/democrats/2008/5/your-flight-has-been-delayed-again_1539

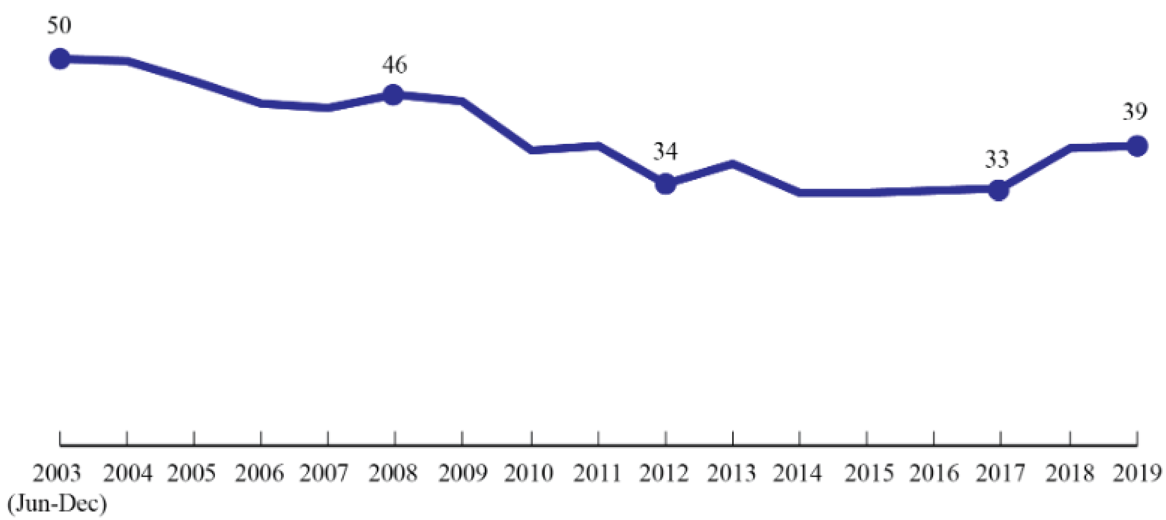
[38] https://apps.bea.gov/iTable/index_industry_gdpindy.cfm

[39] "Satellite Navigation – GPS/WAAS Approaches https://www.faa.gov/about/office_org/headquarters_offices/ato/service_units/techops/navservices/gnss/approaches/

For the combined categories, weather's share of total delay-minutes was 38.7% in 2019.[40] The share of weather in total delay-minutes was trending down between 2003 and 2007 (Figure 8). It fell more rapidly after 2008 with the Great Recession. The share picked up in 2018 and 2019 with a rise in delays due to extreme weather and possibly greater vulnerability to weather during increased activity.

Figure 8

Weather's Share of Delay as Percent of Total Delay-Minutes, by Year



Source: U.S. Department of Transportation, Bureau of Transportation Statistics, "Understanding the Reporting of Flight Delays and Cancellations," https://www.bts.gov/topics/airlines-and-airports/understanding-reporting-

Changes are assessed between the business cycle high years of 2008 and 2019 to abstract from fluctuations in economic activity. During that time, the share of weather delays in total delay-minutes fell from 46% to 39%, by 7 percentage points or 15.2%.[41] Many technologies and rules changes contributed to the decline, including use of instrument landing systems for all-weather flying. Flights to ILS airports are assumed to be of average economic importance compared to all airports.

Many factors have contributed to the reduction in flight delays over the decades and growth in use of ILS has been slow in recent years. Data is not available on the contribution of ILS so the calculation of possible magnitudes is bounded only by the overall decline in delay-minutes of 15.2%. In making an estimate, what are believed to be conservative assumptions are used, recognizing that many other measures have contributed to the decline. The estimate is based on on-time arrivals since they were not delayed for reasons other than weather.

[40] U.S. Department of Transportation, Bureau of Transportation Statistics, "Understanding the Reporting of Flight Delays and Cancellations," https://www.bts.gov/topics/airlines-and-airports/understanding-reporting-causes-flight-delays-and-cancellations

[41] The share of delay-minutes is used instead of the number of delay-minutes in assessing changes to partially abstract from delays for which congestion generally may have played a major role.

It is assumed that 1) 79.2% of flights to ILS airports are on-time arrivals in 2019, the same as for all airports,[42] and that 2) the reduction weather delays for all flights to ILS airports is ½-1 percentage points, which is 3.3%-6.6% of the 15.2 percentage point decline in the share of weather in flight delays between 2008 and 2019. Multiplying 79.2% by 15.2% and by 3.3%-6.6% yields a reduction of 0.397%-0.794% of flight minute delays in all airports.[43]

The cost of flight delays was estimated at $61.8 billion in 2019. With a reduction in costs in weather-delayed flights of 00.397%-0.794%, the savings from increased use of ILS would be $24.5-$49.1 million. This is the national benefit in 2019.

Approximately 100-150 runways or 2%-3% of all runways benefit each year from ASP survey validation for runway additions or expansions. Taking 2%-3% of $37.1-$74.2 million yields an estimate of the benefit to passengers in reduced weather delays on runways surveyed by ASP in 2019 of $430,000-$742,000.

[42] U.S. Department of Transportation, Bureau of Transportation Statistics, "Airline On-Time Statistics and Delay Causes," https://www.transtats.bts.gov/OT_Delay/OT_De0.1%layCause1.asp?pn=1
[43] This assumes ILS airports had an average number of runways per airport.

Text Box 3. Lakeland Linder: An Example of Benefits of Expansion in a Smaller Airport

Airport improvement projects can allow more efficient flight paths. In smaller airports this may include switching some flights from visual to instrument flight rules and increasing the numbers of flights. Instrument flight rules increase safety as well as allowing all-weather flying which benefits both airlines, airports, and customers.

The benefits of all-weather flying are exemplified by reduced costs from fewer flight diversions and cancellations. In conjunction with the Master Plan for Lakeland Linder Airport (LAL) in Florida,[1] Amazon Air unofficially and informally indicated that each diversion from Lakeland Linder to another airport or cancellation would, on average, cost it $150,000 per flight. More generally, savings would be expected to vary between cargo and passenger flights, destinations, types of cargo, types of aircraft, availability of alternative landing sites, and other factors.

In the case of Lakeland Linder, a weather technical note to the Master Plan indicated that before the expansion the percent of time weather impacts were poorer than minimums varied from zero to 0.16% for CAT II and CAT III A, B, and C but for CAT I it was 11.29%. CAT l minimums can be reduced to around 1% by airport, flight rule and equipment improvements in this and other airports according to multiple experts.

Typically, the primary economic benefit of expansion in smaller airports is to introduce or allow more flights by larger planes. One expert suggested that having weather economic impacts concentrated on larger planes is not unusual in smaller airports. In addition, smaller planes, for which accidents are more prevalent, gain important safety benefits.

The Leland Linder Airport Master Plan documents project growth of 30% in the number of operations between 2017 and 2023 and 17% growth between 2023 and 2028. The largest percentage growth in fleet mix was in jets and rotorcraft.*

Instrument operations were 16.5% of total operations and were projected to rise to 18% in 2023 and to 19% in 2028. Hundreds of new cargo flights are expected because airlines can be sure of a CAT III approach.

* Lakeland Linder International Airport, “Airport Master Plan,” https://www.flylakeland.com/airport-master-plan

4. Value of Passenger Time Saved with Reduced Flight Delays Due to Airport Improvements

Passengers and cargo shippers benefit from saved time and convenience and increased choice with added or improved runways, all-weather flying, and other changes for which airport obstruction surveys are required. There were 1.0 billion passenger enplanements on U.S. and foreign carriers’ U.S. flights in 2018 (Table 7).

The FAA recommended using a value of time for air passengers of $38.90-$58.30 based on 2015.[44] Updating the value to 2019 by 7% to allow for changes in earnings to 2019 results in a range of $41.62-$63.38. These values would be lower if the alternative use of some passenger time was in less

[44] U.S. Department of Transportation, Federal Aviation Administration, “Benefit-Cost Analysis (BCA) for the Airport Improvement Program (AIP),” Section 1: Treatment of Time https://www.faa.gov/regulations_policies/policy_guidance/benefit_cost/media/econ-value-section-1-tx-time.pdf

productive activities than work. For the calculations that follow time is conservatively valued at $20-$30 per hour or 33.3¢-66.6¢ per minute in 2019.

Validation of an unduplicated 100-150 runway projects per year involves about 2%-3% of the nation's 5,090 paved runways. With 1 billion passengers overall (Table 7), if projects whose surveys were reviewed by ASP applied to flights with average traffic, those runways would serve 2%-3% of 1 billion or 20-30 million passengers. If passenger time of 5-10 minutes per flight was saved by availability of expanded and additional runways and more efficient flight paths due to ASP validation of surveys, 100-300 million minutes would be saved. Actual savings may be higher than 5-10 minutes per flight and valuation of time is conservative.

At 33.3¢-66.6¢ per minute, the value of time saved on runways undergoing improvements in 2019 would be $33.3-$200.0 million. This does not include the value of convenience and choice to passengers (including better connections) or the value to shippers and their customers.

5. Benefits of Increased Airport Connectivity

Estimates of the aggregate value of various changes in airport connectivity and activity are combined with tabulations of data on airport improvements to obtain measures of broader impacts. First, the connectivity data is described.

Transportation Research Board Estimates

The Transportation Research Board of the National Academies (TRB) Airport Cooperative Research Program (ACRP) studied of the role of airports in the national economy. The study estimated the passenger service productivity impact of a 1% change in different connectivity measures in 2010 based on industry value added in 20 metropolitan statistical areas (MSAs).[45] The TRB approach measures i*ncremental* benefits of changes and takes into account effects on the system as a whole of changes in each airport *without the double counting* that would occur if estimates for states or communities were added. The TRB study did a heroic job of generating incremental estimates from a great many inconsistent data sources. While the difficulties limit the quality of the estimates, the analysis provides directly related comprehensive measures for the purposes of this study.

The TRB study extrapolated the results to the 3,300 airports in the National Plan for Integrated Airport Systems (NPIAS) which covers airports that at the time were eligible for FAA Airport Improvement Program funding. The 2010 impact values for passenger enplanements and runway length are displayed in Table 13. Dollar values for 2019 which are shown in brackets are derived here by updating 2010 values for purchasing power by 44.2% based on the implicit price deflator for value added in aviation which is a component of the U.S. Department of Commerce GDP accounts. The updated values are used in the subsequent benefit calculations.

[45] Transportation Research Board, Airport Cooperative Research Program, *The Role of U.S. Airports in the National Economy*, ACRP Report 132, 2015 https://www.nap.edu/catalog/22146/the-role-of-us-airports-in-the-national-economy TRB also made estimates of consumer surplus based on price declines. These are not included.

Table 13. Incremental Impacts of Aviation Passenger Activity by Type of Airport (year 2010 values with 2019 updates in brackets)	
Type of Airport	**Incremental Impacts**
Large Hub	All else constant, an additional 10,000 total enplanements per year are correlated with an estimated $3.3 million dollars of direct airport revenue [$4.8 million].
Medium and Small Hub	For both medium and small hubs, all else constant, an additional 10,000 total enplanements are correlated with approximately $1.8 million of revenue [$2.6 million].
Non-hub Primary Airports	All else constant, an additional 10,000 total enplanements at a non-hub primary airport are correlated with a $1.66 million increase in direct revenue {$2.39 million]. Additionally, a 1,000-foot increase in runway length is correlated with $0.13 million in direct revenue[$0.19 million], and 1,000 military operations at $.05 million in direct revenue [$.07 million].
Non-primary Commercial Service Airports, Relievers, and GA Airports	… a 1,000-foot runway length explains $0.01 million in direct revenues for relievers [$0.014 million], $.002 million for nonprimary commercial service airports [$.003 million], and $.001 million for GA airports [$.001 million]…. Additionally, 1,000 GA operations (itinerant plus local) in each of the three classifications correlate to $882 in revenue [$1,272].
Source: Transportation Research Board, Airport Cooperative Research Program, *The Role of U.S. Airports in the National Economy*, ACRP Report 132, 2015, Table 11 https://www.nap.edu/catalog/22146/the-role-of-us-airports-in-the-national-economy	

Note that TRB enplanements and other measures are "all else constant" so they understate the effects of capacity changes that include multiple features of expansions (see Appendix H). These passenger values are used in the present calculations and values for cargo are added later.[46]

FAA Airport Capacity Profiles

FAA airport capacity profiles provide projections of runway throughput capacity changes by airport for 2014-2020 by individual airport. These are aggregated and combined with the 2019 TRB values from Table 15 to compute average annual benefits of the planned changes. **T**he capacity profile data includes percentages of growth for each airport and serves as a convenient proxy for actual changes to which values of connectivity can be applied.

The FAA airport capacity profiles report of July 2014 estimated expected airport runway capacity expansions for the 30 airports in the National Airspace System (NAS), covering airports with 1% or more of total enplanements (defined as large hubs) or with 0.75% or more of total non-military itinerant operations (Table 15).[47] The

[46] The TRB estimates of consumer surplus benefits are not included in the calculations because they are based on price declines which redistribute resources from airlines to passengers rather than applying to the combined benefits to both.

[47] U.S. Department of Transportation, Federal Aviation Administration, *Airport Capacity Profiles*, July 2014 https://www.faa.gov/airports/planning_capacity/profiles/media/Airport-Capacity-Profiles-2014.pdf

report defines capacity as "the hourly throughput that an airport's runways are able to sustain during periods of high demand, represented as the range between the ATC (Air Traffic Control) Facility Reported Rate and a model-estimated rate."[48]

The report goes on the state: "Because capacity changes in response to weather and operational conditions, a capacity rate range was developed for each of three weather conditions--visual, marginal, and instrument. For each, the runway configuration with the highest sustainable throughput has been selected. Note that runway capacity is estimated independently of constraints in the en route or terminal airspace and parts of the airport beyond the runways."[49]

The airports and their operations are shown in Table 14 for three sets of weather conditions defined as:

"Visual: Ceiling and visibility allow for visual approaches, which are specific to each airport.

Marginal: Ceiling and visibility are below visual approach minima, but better than instrument conditions

Instrument: Ceiling less than 1,000 feet or visibility less than 3 statute miles.4 Instrument Flight Rules (IFR) apply and radar separation between aircraft is required."[50]

Table 14. Runway Capacity of Airports in the 2014 FAA Airport Capacity Study (1 of 3)
(arrivals plus departures per hour)

Airport Identifier and Name		Aircraft Operations (Arrivals and Departures) per Hour		
		Visual	Marginal	Instrument
ATL	Hartsfield-Jackson Atlanta International			175-190 (AP)
		216-226 (AP)	201-208 (AP)	183-186 (DP)
		219-222 (DP)	206 (DP)	168-169 (LIMC - AP)
				168-179 (LIMC - DP)
BOS	Boston Logan International	116-125	109-112	84-86

[48] *Ibid*., p.1.
[49] Airport obstruction surveys address aprons around runways, and runway throughput depends on the condition of such areas as well as the runways themselves. Consequently, the estimates are taken to apply to all of the runway-related areas covered by the surveys which ASP reviews.
[50] *Op. cit*., p.4.

Table 14. Runway Capacity of Airports in the 2014 FAA Airport Capacity Study (2 of 3)
(arrivals plus departures per hour)

Airport Identifier and Name		Aircraft Operations (Arrivals and Departures) per Hour		
		Visual	Marginal	Instrument
BWI	Baltimore-Washington Thurgood Marshall International	68-80	64-80	62-64
CLT	Charlotte/Douglas International	176-182	161-162	138-147
DCA	Ronald Reagan Washington National	69-72	69-72	54-64
DEN	Denver International	262-266 (AP)	224-279	224-243
		266-298 (DP)		
DFW	Dallas/Fort Worth International	226-264	194-245	170
DTW	Detroit Metropolitan Wayne County	178-184	163-164	136
EWR	Newark Liberty International	94-99 (AP)	76-84	68-70
		94-100 (DP)		
FLL	Fort Lauderdale-Hollywood International	74-82	66-72	56-66
HNL	Honolulu International	117-120	91-105	60-77
IAD	Washington Dulles International	150-159 (AP)	112-120 (AP)	108-111 (AP)
		156-164 (DP)	136-145 (DP)	125-132 (DP)
IAH	Houston George Bush Intercontinental	172-199	152-180	144-151
JFK	New York John F. Kennedy International	84-87 (AP)	85-86	74-84
		90-93 (DP)		
LAS	Las Vegas McCarran International	122-128	106-111	78-83

Table 14. Runway Capacity of Airports in the 2014 FAA Airport Capacity Study (3 of 3)
(arrivals plus departures per hour)

Airport Identifier and Name		Aircraft Operations (Arrivals and Departures) per Hour		
		Visual	Marginal	Instrument
LAX	Los Angeles International	167-176	147-153	133-143
LGA	New York LaGuardia	80-86	76-77	74-76
MCO	Orlando International	160-171	148-161	144
MDW	Chicago Midway International	64-84	64-74	52-70
MEM	Memphis International	144-160	133-150	111-134
MIA	Miami International	132-150	132-148	100-104
MSP	Minneapolis-Saint Paul International	156-167	142-151	114-141
ORD	Chicago O'Hare International	214-225	194-200	168-178
PHL	Philadelphia International	120-126	94-96	84-88
PHX	Phoenix Sky Harbor International	138-145	108-109	96-101
SAN	San Diego International	48-57	48-52	48
SEA	Seattle-Tacoma International	100-112	86-100	76-78
SFO	San Francisco International	100-110	90-93	70-72
SLC	Salt Lake City International	148-150	138-140	114-120
TPA	Tampa International	113-115	95-115	90-95

Note: AP = Arrival Priority Configuration. DP = Departure Priority Configuration. LIMC = Low Instrument.
Source: U.S. Department of Transportation, Federal Aviation Administration, *Airport Capacity Profiles*, July 2014, Table 1 https://www.faa.gov/airports/planning_capacity/profiles/media/Airport-Capacity-Profiles-2014.pdf

The FAA study estimated percentage changes in airport runway capacity for each airport for visual, marginal and instrument weather conditions. The estimated percentage improvements in capacity between 2004 and 2010 were applied to the midpoints of the initial capacity levels from Table 15 to obtain an increase in capacity for each airport in each type of weather (Table 15).

Table 15. Expected Increased Operations Capacity of Airports, 2014-2020, Based on the 2014 FAA Runway Capacity Study (1 of 2)
(arrivals plus departures per hour)

Identifier	Airport Name	Mid-Point of Change in Capacity		
		Visual	Marginal	Instrument
ATL	Hartsfield-Jackson Atlanta International			
	AP	17.68	14.32	10.95
	DP	17.64	14.42	11.04
	AP			8.43
	DP			10.41
BOS	Boston Logan International	2.41	4.42	14.45
BWI	Baltimore-Washington Thurgood Marshall International	0.74	2.16	1.89
CLT	Charlotte/Douglas International	21.48	17.77	12.83
DCA	Ronald Reagan Washington National	0.71	0.71	1.18
DEN	Denver International			
		23.76	27.67	30.36
		36.66		
DFW	Dallas/Fort Worth International	14.70	12.25	6.80
DTW	Detroit Metropolitan Wayne County	7.24	14.72	19.04
EWR	Newark Liberty International			
		11.58 (AP)	29.60	4.14
		10.67 (DP)		
FLL	Fort Lauderdale-Hollywood International	46.02	36.57	46.97
HNL	Honolulu International	n.a.	n.a.	n.a.
IAD	Washington Dulles International			
	AP	6.18	31.32	26.28
	DP	3.20	1.41	2.57
IAH	Houston George Bush Intercontinental	29.68	21.58	4.43
JFK	New York John F. Kennedy International			
	AP	4.28	5.13	7.11
	DP	3.66		
LAS	Las Vegas McCarran International	6.25	5.43	5.64
LAX	Los Angeles International	6.86	4.50	5.52
LGA	New York LaGuardia	2.49	4.59	6.00
MCO	Orlando International	6.62	3.09	1.44
MDW	Chicago Midway International	n.a.	n.a.	n.a.
MEM	Memphis International	9.12	1.42	4.90
MIA	Miami International	1.41	2.80	6.12
MSP	Minneapolis-Saint Paul International	4.85	1.47	1.28

Table 15. Expected Increased Operations Capacity of Airports, 2014-2020 Based on the 2014 FAA Runway Capacity Study (2 of 2)
(arrivals plus departures per hour)

Identifier	Airport Name	Mid-Point of Change in Capacity		
		Visual	Marginal	Instrument
ORD	Chicago O'Hare International			
	AP	30.73	53.19	58.82
	DP	74.63		
PHL	Philadelphia International	7.38	31.35	7.74
PHX	Phoenix Sky Harbor International		20.62	12.81
SAN	San Diego International	1.05	1.00	0.00
SEA	Seattle-Tacoma International	5.30	6.72	3.08
SFO	San Francisco International	4.20	2.75	2.13
SLC	Salt Lake City International	4.47	5.56	4.68
TPA	Tampa International		6.30	7.40

Note: AP = Arrival Priority Configuration. DP = Departure Priority Configuration.
n.a. = not available
Source: U.S. Department of Transportation, Federal Aviation Administration, *Airport Capacity Profiles*, July 2014, Tables 1 and 2 https://www.faa.gov/airports/planning_capacity/profiles/media/Airport-Capacity-Profiles-2014.pdf

The runway capacity changes were added across airports for each type of weather, with approximate average values used where there were multiple entrees for a type of weather and/or type of arrival or departure. Greater weight was given to visual conditions in this calculation to reflect their typically greater prevalence. The resulting overall increase in capacity is 283 arrivals or departures per hour.

Since the change in the FAA capacity analysis applies to 6 years of runway development, 1/6 of 283 or 47 is taken as the increase in departures or arrivals per hour for runway expansions in a single year. This capacity estimate is reduced by 10% to 42 *per hour* to roughly remove effects of improvements in flight procedures or air traffic control technologies accompanying the runway improvements (see Text Box 4).[51] The adjusted capacity per hour of 42 equals 368,000 additional departures and arrivals per year or 184,000 departures per year.

Text Box 4. Value of Runway Improvements

"Runway improvements typically offer greater benefits than do technology or procedural improvements…. new parallel runways that are spaced at least 3,600 feet apart, will have the greatest impact on capacity for arrivals (2,500 feet apart for departures)."

Source: U.S. Department of Transportation, Federal Aviation Administration, *Airport Capacity Profiles*, July 2014, p.6
https://www.faa.gov/airports/planning_capacity/profiles/media/Airport-Capacity-Profiles-2014.pdf

[51] FAA capacity constraints require operations at less than full flight capabilities at some airports which reduces the usable throughput. However, capacity is underestimated because the calculations based on the capacity data do

Combining Capacity and Connectivity Passenger Service Estimates

FAA expected capacity changes for all NPIAS airports with runway additions and extensions are combined with the updated 2019 TRB estimates of the value of productivity impacts of increased airport connectivity for passenger flights – which are in brackets in Table 15. The value of 10,000 additional enplanements estimated in the TRB study is $4.8 million in revenue in year 2019 purchasing power for direct airport revenue in large hubs. The TRB estimate is $2.6 million for medium and small hub airports and $2.39 million for non-hub primary airports. Because of the greater share of enplanements in larger airports, a combined value across airport sizes of $3.9 million per 10,000 additional enplanements is used.[52]

With $3.9 million per 10,000 takeoffs based on TRB, 184,000 takeoffs per year enabled by runway additions and expansions in the FAA study produces an estimated value of $72.2 million in 2019. Since $72.2 million represents the value of runway and related improvements in one year in NPAIS airports, it already reflects the involvement of ASP reviews.

Including International Air Cargo

The TRB study also included incremental estimates for international air cargo based on effects on productivity in U.S. manufacturing and wholesale trade. TRB found that a 2010 "1% increase in enplaned air cargo reflects $173 million boost in direct value added,..."[53] This was based on a method that the study notes underestimated the value.

The percentage of runways being added or rehabilitated is compared with the TRB use of a 1% increase in air cargo to see what percentage of that value is applicable to the contribution of ASP. The 3,332 NPIAS airports have 5,000 paved runways.[54] An estimated 2%-3% of paved runways had airport obstruction surveys that were validated by ASP in 2019. If only half of those runways carried a significant amount of international cargo, that would represent 1%-1-1/2% of all paved runways. Applying 1%-1-1/2% to the TRB value of $173 million yields a preliminary estimate of the contribution of ASP to benefits of international air cargo of $173-$259.5 million in 2010.

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not include growth in activity between the 2017 midpoint of the 2014-2020 period and 2019. Since these factors are partially offsetting, no adjustment is made for them.

[52] The TRB study did not explicitly include in its estimates non-runway development for which funds are eligible under the FAA Airport Improvement Program – such as land acquisition, drainage, taxiway construction, apron construction, improved lighting, and signage. Some of these are included in safety aspects of airport obstruction surveys reviewed by ASP. The TRB statistical analysis may include a portion implicitly, but to the extent they are not, benefits are understated. The FAA estimates of increased capacity, on the other hand, do include these effects.

[53] Transportation Research Board, Airport Cooperative Research Program, *The Role of U.S. Airports in the National Economy*, ACRP Report 132, 2015, Table 15 https://www.nap.edu/catalog/22146/the-role-of-us-airports-in-the-national-economy

[54] U.S. Department of Transportation, Federal Aviation Administration, "U.S. Transportation Secretary Elaine L. Chao Announces $157 Million in Infrastructure Grants to 34 Airports in 19 States and One Territory," Press Release, September 30, 2019 https://www.faa.gov/news/press_releases/news_story.cfm?newsId=24276

Based on these considerations the combined incremental value of runway additions and expansions for passenger flights together with international cargo aviation based on 2010 is estimated as $43.3 + $173-$259.5 million or $216.3 $302.8 million. Updating the value to 2019 by the 80.5% increase in value added in aviation during 2010-2019 yields an estimate of $390.4-$546.6 million. This excludes benefits of domestic air cargo.[55]

TRB provides standard deviations for the service variables used in its multiple regression analyses.[56] These are very large, ranging from 20% of mean values to over 100% for some measures in some years. This and TRB's assessment of underestimation are taken into account by expanding the range of the combined estimates for full loss by 50% in each direction, which results in values of $195.2-$819.8 million.

Summary and Synthesis of Quantitative Evidence on Socio-Economic Benefits

Five estimates of aspects of benefits of ASP's principal review and validation functions under a scenario for complete loss of benefits are summarized in Table 16. The estimates are generally conservative. They differ in the scope of benefits covered. The values vary greatly and are subject to wide ranges. Combined estimates are formed for the two scenarios as follows:

Full Loss of Incremental Value

> Estimate 1 is very limited and is much smaller than the sum of Estimates 2 and 3 which it includes, so the sum of Estimates 2-5 is used. This results in a combined value for the full loss of incremental value scenario of $229.5 million - $1.02 billion in 2019.
>
> The bulk of the contribution comes from Estimates 4 and 5, and especially all of Estimate 5 which does not need to assume a proportion of benefits attributable to ASP.

Partial Loss of Incremental Value

> Estimates of the value of the principal services of the ASP program for the partial incremental loss scenario, which applies if others performed the services with less capability, less timeliness and/or higher cost, are based on 10%-20% of the full value loss. The loss in the partial loss scenario is $23.0-$204.5 million.

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[55] Appendix J provides an illustration of the value of speedier e-commerce delivery.

[56] Transportation Research Board, Airport Cooperative Research Program, *The Role of U.S. Airports in the National Economy*, ACRP Report 132, 2015 https://www.nap.edu/catalog/22146/the-role-of-us-airports-in-the-national-economy TRB also made estimates of consumer surplus based on price declines. These are not included.

Table 16. Summary of 2019 Socio-Economic Benefit Measures under Scenario for Complete Loss of Value of Principal ASP Review and Validation of Survey Plans and Surveys		
Benefit Measure	**Order of Magnitude of Economic Value**	**Coverage**
1. Savings from use of WAAS in aviation	$86,000-$778,000	Limited estimate based on DoT update of an earlier rough estimate the value of benefits of WAAS in flying in bad weather and number of ASP reviews.
2. Fuel cost savings with continuous descent arrivals (CDAs**)**	$578,000-$1,734,000	Fuel cost savings with CDAs which require using RNAV and RNP, assumed frequency of CDAs and number of ASP reviews. Does not include savings in labor and other costs or environmental benefits.
3. Reduced costs of flight delays due to weather with ILS	$430,000-$742,000	Obtained by applying a conservative percentage of the decline in flight delay-minutes due to weather for runways using ILS and covered by ASP surveys to data on the national cost of flight delays.
4. Value of passenger time saved with reduced flight delays due to airport improvements	$33.3-$200.0 million	Assumed savings of 5-10 minutes per flight for passengers using runways affected by expansions and improvements requiring ASP surveys. Based on a conservative estimate of the value of passenger's time. Does not include the value of convenience and choice to passengers (including better connections) or the value to shippers and their customers.
5. Benefits of increased airport connectivity	$195.2-$819.8 million	Incremental value of connectivity for passenger services in runways covered by ASP surveys, based on airport-by-airport capacity expansions and a TRB cross-airport econometric analyses of connectivity, plus effects of additional international cargo services on productivity in manufacturing and wholesale trade. Does not include domestic air cargo.

The estimates understate the losses without ASP for several reasons:

- They do not include many kinds of benefits, e.g. non-fuel cost savings in Estimate 2, non-passenger costs in one of two values averaged in Estimate 3 and buffers in flight schedules in the other, non-passenger flight delay costs in Estimate 4, and domestic cargo in Estimate 5
- Some parameters were chosen at low levels to be conservative. For example, in Estimate 3 for reduced costs of flight delays due to weather with ILS assumes that only 3.3%-5.5% of recent declines in weather delays are attributable to increased use of ILS. Estimate 4 for passenger time saved with airport improvements assumes only 5-10 minutes per flight and a low range is used for the value of passenger time

- The benefits were applied to 100-150 runways, judged as the number to be reviewed by ASP in a year based in its downloads. This is much lower than implied by the 688 AIP grants for construction and reconstruction in the year
- Data limitations prevented the inclusion of safety and environmental benefits
- The estimates apply to the program's reviews and validation of plans and surveys and not its additional functions

The estimates are for a single year's benefits. Future benefits of continuation of the program are taken into account in the analysis of present discounted values after multiplier effects are included.[57]

Incorporating Multiplier Effects

An economic multiplier takes into account the indirect effects on suppliers and the induced effects on the rest of the economy. The TRB study found the national multiplier for value added typically was between 1.5 and 2.0 for number or passenger airlines, nonstop departures and nonstop flights, but was 3.36 for international cargo.[58] In comparison, analysis of benefits of aviation in Pennsylvania based on the commonly used 2012 national IMPLAN model[59] yielded an output multiplier for all of aviation of 1.68.[60] In the FAA national data for 2016 in Appendix A, the ratio of total output which includes multiplier effects to primary output (value added) is 2.5 for airline operations and 4.2 for airport operations.[61] FAA includes a MITRE Corporation analysis of flight delay propagation along with the agency's requirements for cost-benefit analysis. The multipliers are clustered around 1.5.

[57] Benefits of ASP activities in a single year continue in subsequent years but only until the next survey is done. In practice, if a survey is not adequate, the deficiencies would either be rectified by the existing contractor or another contractor would have to be selected. This might involve a delay and loss of benefits of only up to a couple of years. This is different from the present discounted values that discount benefits of program activity in future years.
Also, substitution among airports, aircraft, flight patterns, and modes of transportation potentially could reduce losses from FAA restrictions. Alternatives might cost more in time and money and possibilities for gains from substitution could be limited during the time it takes for a survey to be approved.
The two considerations work in opposite directions; neither is included in the estimates.

[58] Transportation Research Board, Airport Cooperative Research Program, *The Role of U.S. Airports in the National Economy*, ACRP Report 132, 2015, table 19, p.37 and table 23, p.39 https://www.nap.edu/catalog/22146/the-role-of-us-airports-in-the-national-economy

[59] RESI, "What is IMPLAN?," Towson University, June 15, 2006 http://cier.umd.edu/RGGI/documents/IMPLAN.pdf

[60] Wilbur Smith Associates with assistance from Parsons Brinkerhoff, *Thee Economic Impact of Aviation in Pennsylvania*, Pennsylvania Department of Transportation, Bureau of Aviation, October 2011, p.28 https://www.penndot.gov/Doing-Business/Aviation/Planning%20and%20Zoning/Documents/2011%20Aviation%20Economic%20Impact%20Study%20Technical%20Report.pdf

[61] U.S. Department of Transportation, Federal Aviation Administration, *The Economic Impact of Civil Aviation on the U.S. Economy*, January 2020, Tables 3 and 4 https://www.faa.gov/about/plans_reports/media/2020_jan_economic_impact_report.pdf

To be conservative a multiplier of 1.5 is used.[62] Using a 1.5 multiplier the economy-wide values of the ASP NGS program survey reviews for the two scenarios in 2019 are:

Full loss of Incremental Value	\$344.3 million - \$1.53 billion
Partial Loss of Incremental Value	\$34.4 million - \$306.0 million

Present Value of Future Benefits

The present value of ASP benefits is based on its principal airport obstruction survey review and validation functions. To determine the value of future benefits the present discounted value of the estimates is calculated assuming those benefits grow with GDP for 10 years. This is not to indicate a specific path for benefits but only to indicate the cumulative order of magnitude when the program persists. The values are for the years 2020-2029 discounted to 2019 in dollars of 2019 purchasing power.

The benefit estimates were trended based on the Congressional Budget Office January 2020 year-by-year projections of real GDP[63] which generates estimates in dollars of 2019 purchasing power. These were modified to incorporate the Congressional Budget Office preliminary update of GDP estimated for 2020 and 2021 as of April 23, 2020 and allow for the passage of stimulus legislation through April 24.[64]

Present discounted values are calculated with a discount rate of 7% which is recommended by OMB, Alternatives of 5% and 3% are also computed. The discount rate refers to the cost of capital *above* the rate of inflation and includes risk as well as the cost of capital. The present discounted values are shown in Table 17.[65]

> … at a minimum under the complete loss scenario the present value of the program is billions of dollars, and under a partial loss of benefits scenario at a minimum it is hundreds of millions of dollars.

Using a 7% discount rate, the present value of the loss benefits without the NGS ASP program reviews of survey plans and surveys over the next ten years, assuming the program remains as in 2019, is \$3.0-\$13.2 billion based on the full incremental value of the program and national economic growth.

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[62] Stephen Welman, Ashley Williams and David Hechtman, *Calculating Delay Propagation Multipliers for Cost-Benefit Analysis*, MITRE Corporation, 2010 https://www.faa.gov/regulations_policies/policy_guidance/benefit_cost/media/faabca.pdf

[63] U.S. Congress, Congressional Budget Office, *The Budget and Economic Outlook: 2020-2030*, January 2020, Appendix B https://www.cbo.gov/publication/56073

[64] One percent is added to the previous CBO projection for 2022 to allow for bounceback and effects of already legislated and subsequent government stimulus programs. CBO only provides a 4th quarter to 4th quarter percentage change in GDP for 2021 so the annual value had to be interpolated. Alternative numbers for GDP in 2020-2022 would not have a major effect on the discounted values over a decade. U.S. Congress, Congressional Budget Office, "CBO'S Current Projections of Output, Employment, and Interest Rates and a Preliminary Look at Federal Deficits for 2020 and 2021," Blog, posted by Phill Swagel, April 24, 2020 https://www.cbo.gov/publication/56335?utm_source=feedblitz&utm_medium=FeedBlitzEmail&utm_content=812526&utm_campaign=Express_2020-04-24_13:30:00&utm_medium=FeedBlitzEmail&utm_content=812526&utm_campaign=Express_2020-04-24_13:30:00

[65] Without allowing for economic growth the present discounted values would be lower by less than 10%.

Under a scenario with an alternative source that is 80%-90% as effective in term of capability and/or cost (loss of 10%-20%), the cumulative loss with the NGS ASP program with a 7% discount rate is $296 million -$2.6 billion.

The wide variation reflects the use of several methods and uncertainty in the data. However, at a minimum under the complete loss scenario the present value of the program is billions of dollars and under a partial loss of benefits scenario at a minimum it is hundreds of millions of dollars.

Table 17. Present Discounted Value of Benefits of the NGS Aeronautical Survey Program, 2020-2029, under Alternative Scenarios and Discount Rates
(billions of 2019 dollars)

Scenario	Discount Rate		
	3%	5%	7%
Full loss of incremental value	$3.7-$16.6	$3.3-$14.7	**$3.0-$13.2**
Partial loss of incremental value	$0.4-$3.3	$0.3-$2.9	**$0.3-$2.6**

Impact on Jobs

The loss of incremental values of the program reflects the level of aviation activity. It can be combined with a ratio of jobs to value for aviation as a whole to estimate the direct numbers of jobs that would be lost in the absence of the NGS Aeronautical Survey Program. A multiplier can then be applied to include indirect and induced job losses.

The national value added by airlines and airports in 2016 which is designated by the FAA as direct output was $159.5 billion and the number of jobs was 1,904,000 (Table 12). Dividing the two results in $83,771 of direct value added per job. Together with the ASP value estimates this implies that under the loss of the incremental value scenario the job loss would be 2,865-10,708 jobs. With the partial loss of incremental value scenario the reduction in jobs would be 287-2,142.

A more realistic assumption is that some of the jobs are relatively fixed, i.e. jobs do not expand fully proportionally with value added, in which case the reductions would be somewhat smaller. To allow for this the estimates of direct job loss are reduced by 20%. The resulting estimate is a direct loss of jobs without ASP under a complete loss of incremental value scenario of 2,292-8,566. Under a partial loss scenario the direct reduction in jobs is 230-1,714.

> …a direct loss of jobs …under a complete loss of incremental value scenario of 2,292-8566. Under a partial loss scenario the reduction in jobs is 230-1,714….
>
> With a multiplier of 1.5 …, under the complete loss of incremental value scenario the reduction in jobs… is 3,438-12,849, and under the partial loss scenario it is 345-2,571.

With a multiplier of 1.5[66] which takes into account the incremental economy-wide effects of aviation, in the

[66] The Transportation Research Board study found incremental employment multipliers of 2.3-5 for various measures of airport connectivity and an employment multiplier of 4.4 for international air cargo. The TRB study used a national multiplier for on-airport direct effects of 2.7. Transportation Research Board, Airport Cooperative

absence of the NGS Aeronautical Survey Program under the complete loss of incremental value scenario the reduction in jobs is 3,438-12,849, and under the partial loss scenario it is 345-2,571.[67]

Impacts on Safety and the Environment

A number of impacts on safety and the environment are possible. Aviation safety has improved greatly for many reasons and it the effects of validation of obstruction surveys cannot readily be separated from other influences. If runways and other facilities were not used because surveys had not been conducted there would be fewer flights and aggregate safety data would be more favorable. It is not clear how or how much safety measures per flight would be affected.

Air pollution under restrictions could come from greater use of fuel per flight with less efficient landings and takeoffs and longer flight paths. However, weight limits would reduce use of fuel. With restrictions, fewer flights would take place as a result of higher costs and the inability of some planes to land and take off in bad weather, which would mean less total use of fuel. There also would be more noise with additional time in the air due to longer landing paths, more circling and more missed approaches.

Available studies of aviation pollution and noise are too incomplete and fragmented to lend themselves to quantifying effects of airport obstruction surveys.[68]

Research Program, *The Role of U.S. Airports in the National Economy*, ACRP Report 132, 2015, table S-1,p.4, table 23, p.39 and table 28, p.48 https://www.nap.edu/catalog/22146/the-role-of-us-airports-in-the-national-economy

[67] An alternative estimate of job losses based on the loss of incremental value would have too wide a range to be useful.

[68] As an example, see Eric P. Dinges, "Determining the Environmental Benefits of Implementing Continuous Descent Arrivals," ATAC Corporation, n.d. https://www.faa.gov/about/office_org/headquarters_offices/apl/research/science_integrated_modeling/media/Environmental%20Benefits%20of%20Continuous%20Descent%20Arrivals.pdf

VI. Influences on Future Needs for NGS Aeronautical Survey Program Services

Some Evolving Trends and Issues

Future needs for the Aeronautical Survey Program's services will be influenced by many factors including:

- Changes in aviation technologies and markets
- Airport surveying and infrastructure development in the aftermath of COVID-19 and the 2020 recession
- The new NSRS to be released by 2023 and geodetic surveying
- Growth of aerial surveying
- Growth of communications towers
- The extent of FAA use of Lidar
- The future importance of satellite imagery
- Contributions of ASP elevation data to dealing with possible effects of increases in extreme weather and sea level rise

Text Box 5. Growing Need for Airport Information

"As airports move toward a more data centric environment, more information about the objects on and around the airport is required."

U.S. Department of Transportation, Federal Aviation Administration, *150/5300-18B - General Guidance and Specifications for Submission of Aeronautical Surveys to NGS: Field Data Collection and Geographic Information System (GIS) Standards*, May 21, 2009, p.11 https://www.faa.gov/regulations_policies/advisory_circulars/index.cfm/go/document.information/documentid/74204

Changes in Aviation Technologies and Markets

While commercial and private aviation will continue to play a critical role in the U.S. economy, it will not have high growth. Graphs of long-term growth in U.S. aviation demand can look impressive, but the growth rates depicted are often around 2% per year (Appendix E). The FAA expects that the bulk of investment in airports will be in terminals and not directly in increased flight capacity.[69] Investment will be reduced by the effects of the Covid economic and health crisis. Even before the 2020 economic crisis the Congressional Budget Office predicted U.S. economic growth of only 1.7% per year for the next decade, assuming current law and no recessions.[70]

[69] FAA projections of capacity needs as of 2015 are available in U.S. Department of Transportation, Federal Aviation Administration, *FACT3: Airport Capacity Needs in the National Airspace System*, 2015 https://www.faa.gov/airports/planning_capacity/media/fact3-airport-capacity-needs-in-the-nas.pdf

[70] U.S. Congress, Congressional Budget Office, *The Budget and Economic Outlook: 2020-2030*, January 2020, Appendix B https://www.cbo.gov/publication/56073 Projections have since been raised to reflect catchup from the crisis. CBO and economic projections typically assume the economy will return to full capacity. However, that capacity can shrink if difficulties persist for a long time, with lower long term growth as a result.

The movement to NextGen and improved aviation weather forecasting has been slow as has the movement toward instrument landing systems among smaller aircraft. Economic difficulties are likely to assure the pace remains slow.

Airport Surveying and Infrastructure Development in the Aftermath of COVID-19 and the 2020 Recession

The faltering economy can prompt development of a large national infrastructure program as occurred after the Great Recession of 2008. Traditional airport development can receive a share of new federal funding. However, interest in increasing traditional flight capacity could be dampened when the economy and air travel is slow and financed of airlines and airports are impaired. Other areas may receive attention including facilities for UAVs and air taxis, spaceports, and facilities in support of the new Space Force.

State and local government financial difficulties reduce the ability to provide matching funds. Even existing plans could be impeded unless matching is waived during the crisis and aftermath.

The economic environment could lead to consolidation of survey firms. Consolidation of firms capable of doing airport obstruction surveys could be hastened by weakened initial and ongoing demand for all airport construction. A national infrastructure program could create demand concentrated among the most capable firms.

Survival of the most capable firms could require the NGS Aeronautical Survey Program to deal with fewer firms and address fewer errors and omissions in airport obstruction surveys. Together with weaker demand for surveys from less investment, this could reduce the workload of ASP. However, when survey firms are learning to adapt to the new NSRS, assistance and corrections could add to the ASP workload.

The New NSRS and Geodetic Surveying

Changes in the NSRS that were scheduled to be in place by the end of 2022 but may be more likely to be ready in 2023 because of impediments due to the coronavirus and its consequences. Better data with the new NSRS could result in more airport obstruction survey updates in the future. If the FAA increased accuracy requirements to take advantage of the modernized NSRS or to meet initiatives such as NextGen, that could require more sophisticated and/or additional surveys.

Providing guidance and review to the FAA to assure that updated circulars fully reflect the revisions in the National Spatial Reference System planned for 202302024 could require additional efforts by staff throughout NGS. Assistance could be required to airport geodetic survey contractors to assure the new methods are used properly and data are valid. This will involve not only ASP program

> Survival of the most capable firms could lead to fewer firms for of the NGS Aeronautical Survey Program to deal with and fewer errors and omissions in airport obstruction surveys. Together with weaker demand, this could reduce the workload of ASP. However, the reduction in construction activity could coincide with the period during which survey firms are learning to adapt to the new NSRS. Assistance and corrections could initially produce an offsetting increase in ASP workload.

staff but also those responsible for the new OPUS and associated tools, Regional Geodetic Advisors, and others in NGS.

With the technology getting more sophisticated and varied, the use of more automated solutions could eventually reduce errors, but at first there could be an increase in errors and omissions because of overreliance on commercial systems that require more knowledge than they appear to and are used without sufficient training. Even among the more qualified firms this could add further to the ASP workload and result in delays until surveys are ready to be approved.

Large airports with many survey projects may wish to tie them to ground zero for accuracy and consistency. It also will be important to preserve physical representation for integrity with new systems such as NexGen. There may be some problems in understanding the new geodetic data for the small percentage of airports that require it.

Better data with the new NSRS could result in an increase in airport obstruction surveys if the FAA increases accuracy requirements to take advantage of the modernized NSRS or to meet initiatives such as NextGen.

If ASP continues to be understaffed, has not added enough new staff above current levels, or has lost key employees to retirement[71] or to other positions at a time of high demand for their skills, the difficulties in managing the transition to the new NSRS could be exacerbated.

Growth of Aerial Surveying

Use of drones in surveying has been expanding rapidly as the technology improves, costs decline, and skills become more widespread. While the NGS Aeronautical Survey Program receives some surveys Data derived from unmanned aerial systems and the benefits in time and money can be large. However. FAA does not yet have procedures for drone use and is only at early stages of deciding what rules to apply. The issue is complicated because in developing requirements the FAA runs afoul of its own rules to protect airports. Consequently, resolution cold take some time. Ultimately the growing use in other sectors and increased deployment in airports, along with the large benefits, could drive changes and lead to widespread airport use.

Growth of Communications Towers

It has been suggested that in the future it could be more important for surveys to check for cell towers and radio transmission towers that, despite being regulated, can slip through unreported.

Text Box 6. An Indication of Growth of Communications

Market Watch projects that the North American 5G chipset market will grow at a compound annual rate of 42.9% between 2019 and 2027.

Source: Press Release, December 26, 2019
https://www.marketwatch.com/press-release/the-north-america-5g-chipset-market-accounted-for-us-4557-mn-in-2019-and-is-expected-to-grow-at-a-cagr-of-429-over-the-forecast-period-2019-2027-to-account-for-us-79344-mn-in-2027-2019-12-26

[71] The wave of baby boomers reaching age 65 will continue for about 7 more years. Many in government service will retire earlier than age 65, making the loss of skills come earlier.

The Extent of FAA Use of LIDAR

Currently, FAA limits use of LIDAR in obstruction analysis to supporting data. Also, FAA must approve any feature class recognition software used in post-processing. Many FAA offices do not have the ability to utilize LIDAR data, requiring them to rely on UDDF files provided by NGS. This is not expected to change rapidly in the future.

The Future Importance of Satellite Imagery

Satellite imagery is not currently approved by FAA for collecting airport data. It is not expected that publicly available satellite data will soon be sufficiently capable for airport obstruction surveys or that its widespread use will be approved quickly by FAA when the technology is further advanced and its cost is reasonable.

Contributions of ASP Elevation Data to Dealing with Possible Effects of Increases in Extreme Weather and Sea Level Rise

ASP reviews elevation data which can then be used by FAA and airports to determine responses to flooding from sea level rise, growth of extreme weather and other sources. For most airports this does not yet appear to be an overriding concern. The estimates of benefits in this study focus on end results such as increased enplanements. They do not directly measure those effects but some considerations may be implicit in airport plans and other data.

ASP did surveys for an airport every 3-5 years until FAA no longer requested that the program do them. Currently, surveys are done on a site on average every 10-12 years. More frequent surveys could become necessary if there was a large or threatening increase in construction near airports or if risks of fire, flooding or growth of foliage increased.

Implications

NGS faces a complex and rapidly changing environment. It will need to fully understand the nature, prospects, magnitudes, and time frames involved with the influences, individually and in combination, so it can better develop strategies and deal with their impacts.

Many of the developments will have impacts not only on ASP but throughout NGS and on NGS as a whole. Meeting the challenges will require a concerted and focused effort. Possible next steps include:

1. More fully describing prospects and their time frames, including developing scenarios for their evolution and impacts, with alternative scenarios where appropriate
2. Developing illustrative quantitative indications for the scenarios individually
3. Developing scenarios for overall impacts on NGS and the choices it faces
4. Enumerating possible overall strategies for NGS addressing the challenges and their requirements for implementation
5. Examining choices and strategies for key sectors and activities of NGS
6. Assisting in incorporating information about prospects and strategies into NGS and NOS strategic plans

VII. Appendices

Appendix A. Benefits of Aviation to the Economy

FAA estimated that airline, general aviation, and airport operations directly contributed $181.4 billion to GDP in 2016 (Table A1). Including aircraft and related manufacturing value added the total was $336 billion. With visitor and travel value added included the total was $706 billion When impacts throughout

Table A1. Direct Output, Total Output, Earnings and Jobs in Civil Aviation and Related Sectors, 2016

Sector	**Primary Output** (value added in $billions)	**Total Output** ($billions)	**Total Earnings** ($billions)	**Total Jobs** (thus.)
Airline operations	131.9	315.6	77.0	1,362
Airport operations	27.6	81.7	26.1	542
Civilian aircraft manufacturing	58.0	144.4	36.2	607
Civilian aircraft engine and engine parts manufacturing	8.0	18.6	4.5	78
Civilian other aircraft engine parts and equipment manufacturing	29.0	71.0	17.8	331
Civilian avionics manufacturing	10.5	25.7	6.5	120
Civilian research and development	13.3	40.4	12.9	223
General aviation operations	21.9	52.3	12.8	226
General aviation aircraft manufacturing	11.6	28.8	7.2	121
Air couriers	24.6	68.7	20.8	512
Subtotal - Direct	336.4	847.3	221.7	4,121
Airline visitor expenditures	357.8	886.5	257.2	6522
General aviation visitor expenditures	4.7	11.7	3.4	86
Travel arrangements	7.1	20.5	6.0	129
Subtotal – “Catalytic” [multiplier effects]	369.6	918.6	266.5	6,736
Total Impact	**706.1**	**1,765.9**	**488.2**	**10,857**

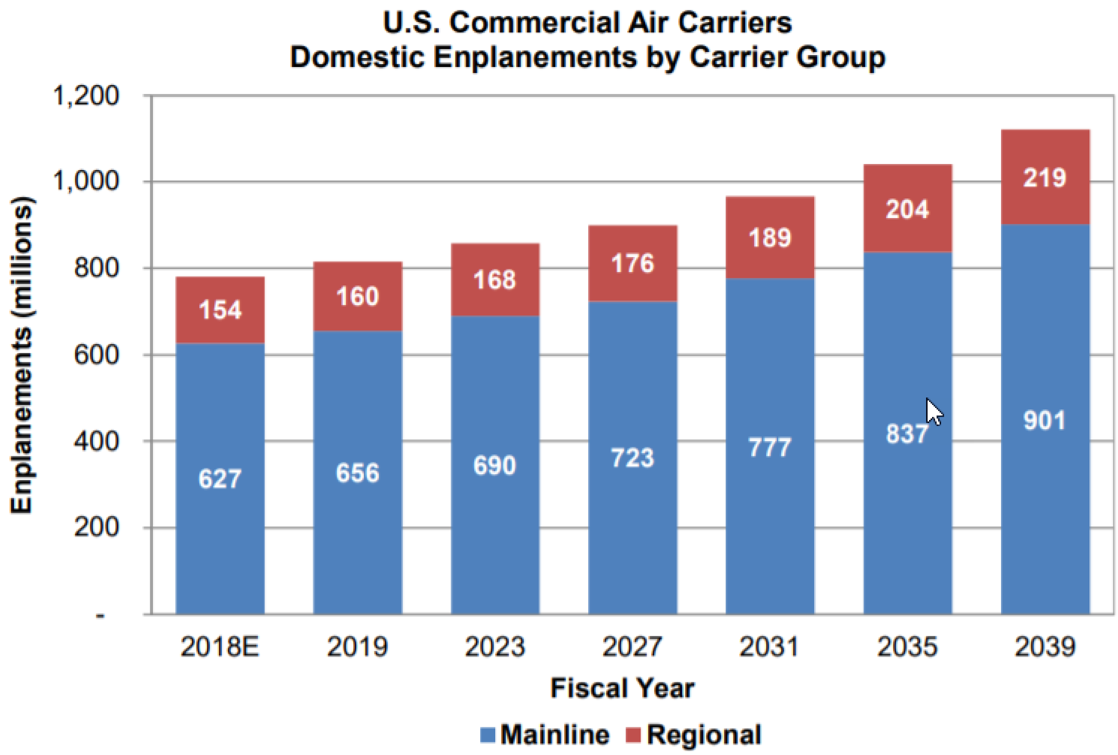
Note: Total output, earnings and jobs include economic multiplier effects.
Source: U.S. Department of Transportation, Federal Aviation Administration, *The Economic Impact of Civil Aviation on the U.S. Economy*, January 2020, Tables 3 and 4
https://www.faa.gov/about/plans_reports/media/2020_jan_economic_impact_report.pdf

Some studies have attempted to estimate the effects of aviation on development of local communities. Obtaining reliable estimates requires distinguishing the effects of community growth on demand for aviation from effects of aviation on the community. This was done for the United States in a 2007 study by Richard Green which used econometric techniques that address two-way causality. Green found that the presence of a major hub had large effects on population growth. However, the volume of cargo activity did not increase economic activity but was only the result of that activity.[72]

[72]Richard Green, "Airports and Economic Development," *Real Estate Economics*, February 2007, pp.91-112 https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1540-6229.2007.00183.x Also see Melanie Green, Melanie, "The Impact of Airport Development on Economic Development," *Duke University 2014 Literature Review*, April 15, 2014 https://sites.duke.edu/urbaneconomics/?p=1248

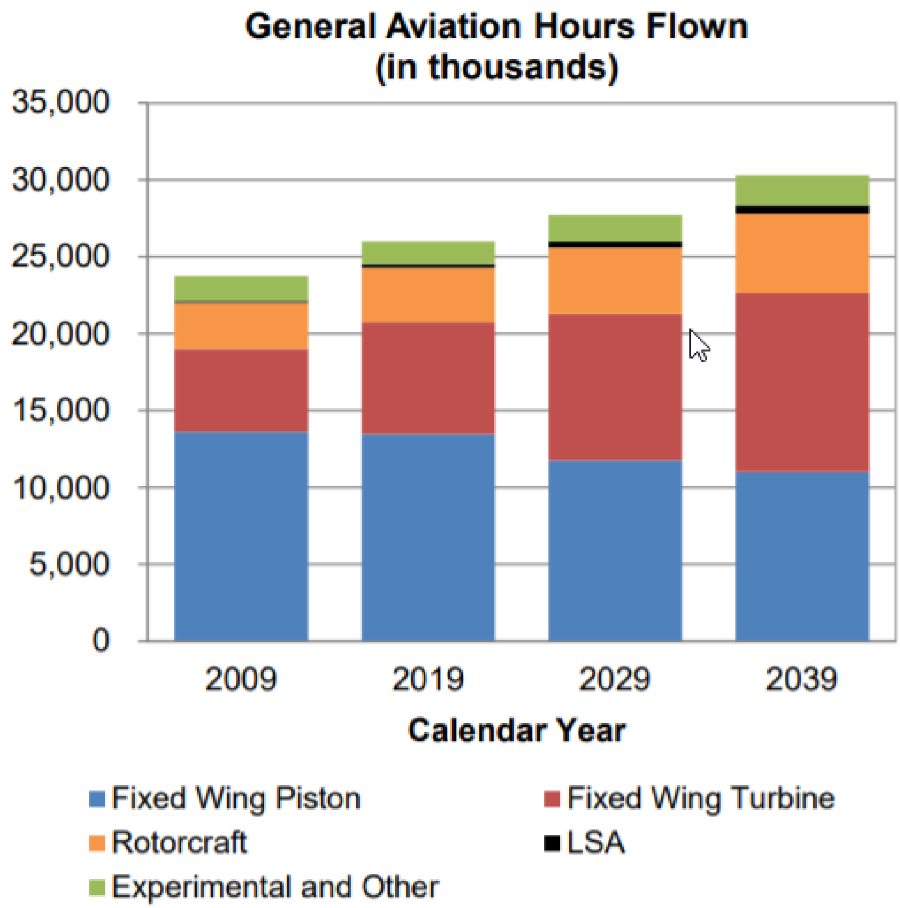
Appendix B. FAA Growth Projections

Figure B1. FAA Passenger Projections



Source: U.S. Department of Transportation, Federal Aviation Administration, *FAA Aerospace Forecast, Fiscal Years 2019-2039*, n.d., p.10 https://www.faa.gov/data_research/aviation/aerospace_forecasts/media/FY2019-39_FAA_Aerospace_Forecast.pdf

Figure B2. FAA General Aviation Hours Projections



Source: U.S. Department of Transportation, Federal Aviation Administration, *FAA Aerospace Forecast, Fiscal Years 2019-2039*, n.d., p.25 https://www.faa.gov/data_research/aviation/aerospace_forecasts/media/FY2019-39_FAA_Aerospace_Forecast.pdf

Appendix C. Aviation Safety

Airplane accidents in the United States frequently involve smaller aircraft, as is indicated in data for 2017, the most recent year for which data are available (Table C1).

Table C1. Accident Summary for Major Segments of U.S. Civil Aviation, 2017

Segment	Accidents	Fatal Accidents	Fatalities
Part 121 Air Carriers	32	0	0
Part 135 Commuter and On-Demand Carriers	**50**	**8**	**16**
Part 91 General Aviation	**1,233**	**203**	**331**
Total US Civil Aviation	**1,315**	**211**	**347**
Source: National Transportation Safety Board https://www.ntsb.gov/investigations/data/Pages/AviationDataStats2017.aspx			

The prevalence of accident with small planes is illustrated by some recent incidents.

On January 16, 2020, a Beechcraft B200 King Air ambulance operated by Life Med crashed in an engine stall after taking off from Unalaska-Tom Madsen Airport (DUT/PADU), Alaska. The airplane ended up 400-500 yards offshore in the waters of Unalaska Bay near Hog Island and sank. The three passengers were rescued but the aircraft was destroyed.[73]

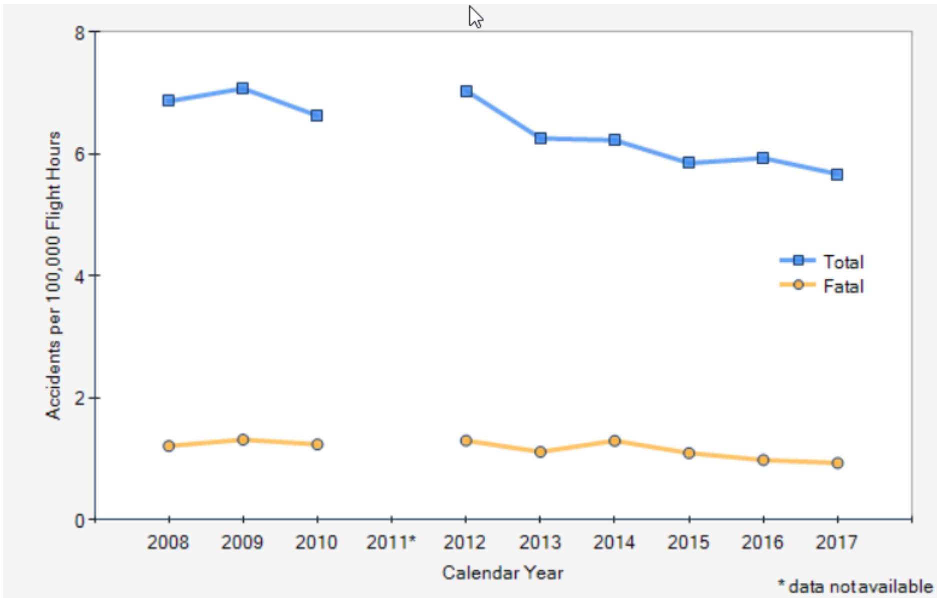
The Sikorsky S-76 B twin engine helicopter that crash on January 26, 2020 took the lives of Kobe Bryant, his daughter and seven others. After taking off from John Wayne airport in Santa Anna, the aircraft went into thickening clouds in the San Fernando Valley a half hour later. Visibility declined with heavy fog in the hills of Calabasas near its destination. The company that operated the helicopter was not licensed to fly by cockpit instruments which was necessary in heavy fog. While the pilot was certified for instrument flight rules, he was bound by the restrictions on the company.

Problems have occurred even with use of Instrument Landing Systems. On March 2, 2016, a Beech 99A airliner operated by Wiggins Airlines from Manchester Municipal Airport, NH (MHT/KMHT) encountered severe turbulence while trying to land at Rockland-Knox County Regional Airport, ME (RKD/KRKD). The turbulence resulted in substantial airframe damage and the plane was diverted to Bangor International Airport (BGR), Maine.

[73]Flight Safety Foundation Aviation Safety Network https://aviation-safety.net/database/record.php?id=20200116-0

General aviation accident rates have been declining (Figure C1). Nevertheless, preliminary data for 2018 reveal 381 general aviation fatalities.[74] There is no direct data on how many accidents, fatalities and injuries were averted by using ILS and related navigation systems.

Figure C1. General Aviation Accident Rates, 2008-2017



Source: National Transportation Safety Board
https://www.ntsb.gov/investigations/data/Pages/AviationDataStats2017.aspx#

Runway incursions continue to be a concern. While they might not be directly affected by the accuracy obstruction surveys, they can be influenced by airport improvement projects that utilize those surveys.

FAA defines a runway incursion as an incident with an aircraft in potential conflict. Among the causes of runway incursions are aircraft crossing active runways, low visibility, and simultaneous use of active runways. Pilot deviations account for the majority of runway incursions (Table C2).

[74] The total includes 378 on-board fatalities. Source: National Transportation Safety Board, downloaded January 27, 2020 https://www.ntsb.gov/investigations/data/Pages/aviation_stats.aspx

Table C2. Number of Runway Incursions, FY 2015-2019

Year	Operational Incidents	Pilot Deviations	Vehicle/ Pedestrian Deviations	Other	Total
2015	323	881	252	2	1,458
2016	322	943	278	8	1,561
2017	306	1,142	293	7	1,748
2018	345	1,142	335	10	1,832
2019	322	1,119	291	15	1,757
Source: https://www.faa.gov/airports/runway_safety/statistics/					

Appendix D. Aviation Technologies and Infrastructure

Figure D1

National Infrastructure Elements and Services

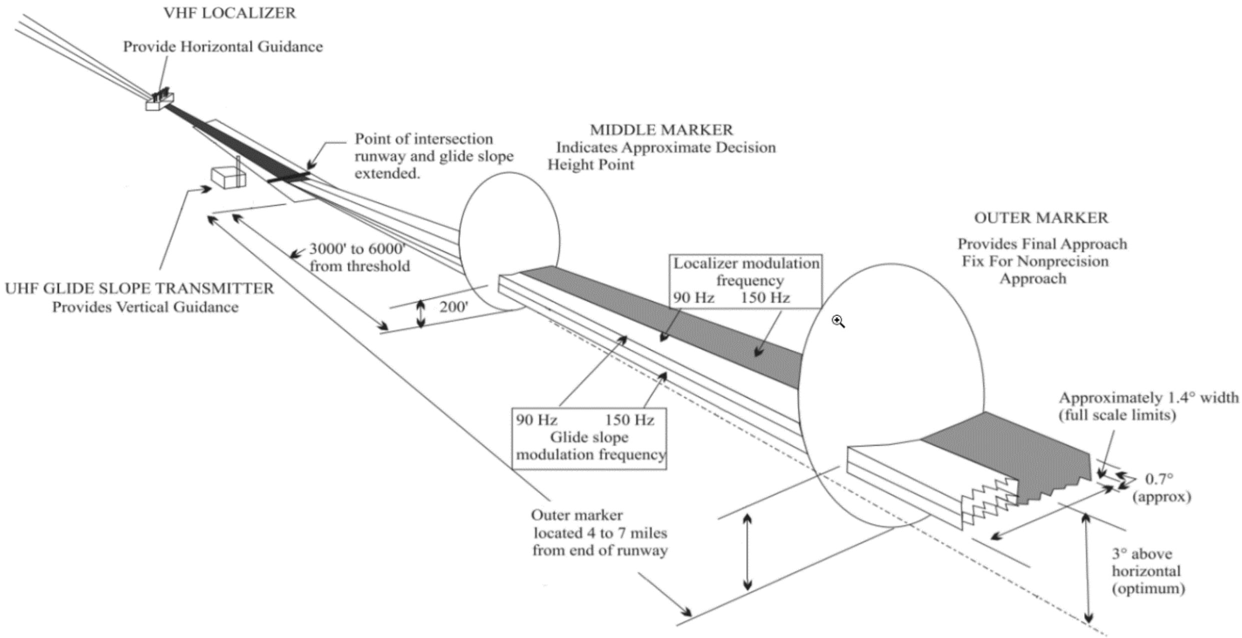
Operational Services		Supporting Systems/Infrastructure			
		Ground Based NAVAIDs	GNSS	Self-Contained on-Board Systems	Airport Lighting
Conventional Navigation Operations	**En Route**	VOR (Victor and Jet routes) VORTAC (Victor and Jet routes) TACAN* DME (fix definition) NDB (in Alaska and for some offshore airways)	GPS, SBAS (approved as a substitute for NDB, DME)	Inertial	N/A
	Arrival and Departure	VOR (SIDs, STARs) VORTAC (Victor and Jet routes) TACAN* (SIDs, STARs) DME (fix definition) NDB	GPS, SBAS (approved as a substitute for NDB, DME)	Inertial	N/A
	Approach & Landing				
	Instrument Approach	ILS, Localizer, LDA VOR DME NDB TACAN* Radar approaches (ASR)*	N/A	Barometric altimetry	Lighting as required for type of operation and/or minima requirements. See AC 150/5300-13
	Vertical Guidance for Instrument Approach	ILS, PAR*	See "Area Navigation Operations" below	Barometric altimetry, radar altimetry, baro-VNAV, EFVS/HUD***	Lighting as required for type of operation and/or minima requirements. See AC 150/5300-13
Performance Based Navigation (PBN) Operations	**En Route**	DME/DME**	GPS, SBAS	Inertial (as part of a multi-sensor system)	N/A
	Arrival and Departure	DME/DME**	GPS, SBAS	Inertial (as part of a multi-sensor system)	N/A
	Approach & Landing				
	RNAV and RNP Instrument Approach (horizontal guidance)	N/A	GPS, SBAS,GBAS	Inertial (as part of a multi-sensor system), barometric altimetry, baro-VNAV	Lighting as required for type of operation and/or minima requirements. See AC 150/5300-13
	RNAV and RNP Instrument Approach (with vertical guidance)	N/A	SBAS, GBAS	Barometric altimetry, baro-VNAV, EFVS/HUD***	Lighting as required for type of operation and/or minima requirements. See AC 150/5300-13

* Primarily used by DoD.
** Legacy and backup services.
*** While not a navigation system, EFVS/HUD acts to mitigate risk and credit is given for its use in operational approvals.

Source: U.S. Departments of Defense, Homeland Security and Transportation, *2017 Federal Radionavigation Plan, p.5-16*
https://www.navcen.uscg.gov/pdf/FederalRadioNavigationPlan2017.pdf

Figure D2

Instrument Landing System



Source: Wikipedia, "Introduction to ILS," downloaded January 14, 2020
https://en.wikipedia.org/wiki/Instrument_landing_system

Appendix E. FAA Facilities and Requirements

Figure E1. FAA Regions and Property Operations

Source: https://www.faa.gov/about/office_org/headquarters_offices/arc/

FAA Circulars

FAA Advisory Circular (AC) 150/5300-16 - General Guidance and Specifications for Aeronautical Surveys: Establishment of Geodetic Control and Submission to the National Geodetic Survey (NGS)

FAA Advisory Circular (AC) 150/5300-17 – Standards for Using Remote Sensing Technologies in Airport Surveys

FAA Advisory Circular (AC) 150/5300-18 - General Guidance and Specifications for Submission of Aeronautical Surveys to NGS: Field Data Collection and Geographic Information System (GIS) Standards

Safety Critical Data

The safety critical survey data defined by FAA AC 150/5300-18B is available in Section 4.1.3. The following list of feature classes, as defined in Chapter 5, is considered Safety Critical data. All aspects of these feature classes, including geometry, accuracy requirements, data capture rules, and attributes are considered safety critical data. The feature classes are:

Navaids
Obstacles
Runway End
Touchdown Lift Off area
Airport Control Points (specifically Airport Elevation, Touchdown Zone Elevation, Displaced Threshold, Stopway End[75]
Runway
Stopway
Taxiway
Visual Aids

There are two types of Navaids: Electronic and Visual. The item refers to "Electronic" Navaids.[76]

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[75] The feature class "Airport Control Point" in the 18B schema includes many types of features are which are to be reported, including the geodetic control stations and runway profile data in addition to the points listed with "Airport Control Points" above.

[76] There are two types of Navaids: Electronic and Visual. The item refers to "Electronic" Navaids.

Appendix F: Projects Eligible for FAA Airport Improvement Program Grants

Table F1. Projects Eligible and Ineligible for FAA Airport Improvement Grants

Eligible Projects	Ineligible Projects
Runway construction/rehabilitation	Maintenance equipment and vehicles
Taxiway construction/rehabilitation	Office and office equipment
Apron construction/rehabilitation	Fuel farms hello
Airfield lighting	Landscaping
Airfield signage	Artworks
Airfield drainage	Aircraft hangars owned and operated by airport
Land acquisition	Industrial park development
Weather observation stations (AWOS)	Marketing plans
NAVAIDS such as REILS and PAPIs	Training
Planning studies	Improvements for commercial enterprises
Environmental studies	Maintenance or repair of buildings
Safety area improvements	
Airport layout plans (ALPs)	
Access roads only located on airport property	
Removing, lowering, moving, marking and lighting hazards	
Glycol Recovery Trucks/Glycol Vacuum Trucks owned and operated by airport	
Source: https://www.faa.gov/airports/aip/overview/	

Appendix G. Airport GIS Survey Spending

Spending on Airport GIS obstruction surveys under the FAA Airport Improvement Program is estimated based on the number of airports, the frequency of surveys and the cost of the surveys. The calculation provides a check on the number of surveys ASP receives in a year from FAA. The information utilized is based on data from ASP and interviews.

The 3,332 NPIAS airports have 5,090 paved runways[77] and additional features of interest. About half of runways do not require surveys even when surveys were done long ago – because significant changes have not occurred to the airports or their surroundings. The average airport conducts a GIS survey every 10-12 years and the average survey costs $80,000-$100,000 per runway, including both runway ends. A large airport can have over 100 GIS surveys conducted as part of a project. some airports

If surveys were every 12 years at the $80,000 per survey, based on 2,500 paved runways, total spending for the nation in a year would be 1/12 x 2,500 x $80,000 million or $16.7 million for 208 surveys. If surveys were done every 10 years at $100,000 cost per survey the cost nationally in a year would be 1/10 x 2,500 x $100,000 or $25.0 million for 250 surveys. NGS downloads suggest a smaller number of surveys.

Survey plans and surveys for a single runway may be submitted to ASP multiple times across multiple years because they contain different elements or had to be revised. Consequently, ASP does not have a count on the number of unduplicated surveys received in a year. The number of downloads from FAA was 630 in FY2019 of which 353 was for survey data (Table 1). This is generally consistent with the 100-150 surveys being conducted in a year at a cost of $8-$15 million.

[77] U.S. Department of Transportation, Federal Aviation Administration, "U.S. Transportation Secretary Elaine L. Chao Announces $157 Million in Infrastructure Grants to 34 Airports in 19 States and One Territory," Press Release, September 30, 2019 https://www.faa.gov/news/press_releases/news_story.cfm?newsId=24276

Appendix H. Underlying TRB Estimates of the Value of Changes in Airport Connectivity and Activity

The Transportation Research Board of the National Academies 2015 study of the role of airports in the national economy examined airport connectivity for 3,300 airports in the National Plan for Integrated Airport Systems (NPIAS).[78] The TRB study estimated the passenger service impact on industry value added in 20 metropolitan statistical areas (MSAs).[79] The results of a 1% change in various connectivity measures in dollars of year 2010 purchasing power are shown in Table H1. A particularly high value was found for domestic nonstop flights.

Table H1. Effect of a 1% Change in Airport Connectivity Measures on U.S. Value Added, 2010
(millions of 2010 dollars)

Connectivity measure	Effect of a 1% Change on Value Added
Number of airlines	201
Domestic nonstop departures	453
Airline hubs served - domestic	374
Domestic nonstop destinations	686
Two or more daily nonstop domestic flights	654
Five or more daily nonstop domestic flights	119
International nonstop departures	192
International nonstop destinations	683
Percent of world GDP service nonstop	67
Percent of world GDP served daily	361

Note: Multifactor productivity analysis which shows the effects of each variable on productivity across industries the economy the other variables unchanged. Based on airports in a sample of 20 metropolitan statistical areas (MSAs).
Source: Transportation Research Board, Airport Cooperative Research Program, *The Role of U.S. Airports in the National Economy*, ACRP Report 132, 2013, Table 18 https://www.nap.edu/catalog/22146/the-role-of-us-airports-in-the-national-economy
Values are updated from 2010 to 2019 based on the GDP price deflator.

Previous studies have confirmed the value of nonstop flights, number of network connections with other airports and other elements of air travel.[80]

[78] Transportation Research Board, Airport Cooperative Research Program, *The Role of U.S. Airports in the National Economy*, ACRP Report 132, 2015 https://www.nap.edu/catalog/22146/the-role-of-us-airports-in-the-national-economy

[79] The 20 MSAs represented 23% of the economy. Results were extrapolated to the national economy.

[80] Mark Israel, *et. al*., "Airline Network Effects and Consumer Welfare," *Review of Network Economics*, 2013, pp.1-36 file:///C:/Users/ileve/Downloads/AirlineNetworkEffectsandConsumerWelfare.pdf and Steven A. Morrison and

Appendix I. Costs of Flight Delays and Cancellations

Data on passenger carrier operating costs per block minute indicate that the costs to airlines of delays and cancellations can be high (Table I1).

Table I1. U.S. Passenger Carrier Operating Cost per Block Minute, 2018
(dollars)

Type of Cost	Cost per Block Minute*
Fuel	27.01
Crew – pilots, flight attendants	23.35
Maintenance	11.76
Aircraft ownership	9.28
Other	2.80
Total	**74.20**

*A block minute includes time from pushing back from the departure gate ("off-blocks"), to arriving at the destination gate ("on-blocks").
Source: Airlines for America https://www.airlines.org/industry/

Additional carrier costs are incurred for extra gates and ground personnel. Passengers can face high costs of lost time and expenses for alternative transportation and lodging. Cargo delays can impose substantial costs on shippers and their customers. Secondary effects of delays on the economy add to the costs.

The 2010 comprehensive NEXTOR (National Center for Excellence for Aviation Operation Research) total delay impact study estimated the cost of all U.S. air transportation delays in 2007 at $32.9 billion.[81] This included $8.3 billion in cost to airlines including crew, fuel, maintenance, and other costs. The cost of passenger time lost due to schedule buffer, delayed flights, flight cancellations, and missed connections was valued at $16.7 billion. In addition, there was a $3.9 billion cost from lost demand, which is an estimate of the welfare loss incurred by passengers who avoid air travel as the result of delays.

Clifford Winston, "Enhancing the Performance of the Deregulated Air Transportation System," *Brookings Papers on Economic Activity* (1989), pp.61-123 https://www.brookings.edu/bpea-articles/enhancing-the-performance-of-the-deregulated-air-transportation-system/

[81] NEXTOR, *Total Delay Impact Study: A Comprehensive Assessment of the Costs and Impacts of Flight Delay in the United States*, October 2010 http://www.trb.org/Main/Blurbs/164271.aspx

The NEXTOR estimate of $32.9 billion in total costs compares with an estimate by the Congressional Joint Economic Committee in 2008 of costs of $40.7 billion in 2007 of which $4.0 billion was the result of indirect effects on the economy.[82]

[82] U.S. Congress, Joint Economic Committee Majority Staff, *Your Flight Has Been Delayed Again: Flight Delays Cost Passengers, Airlines, and the U.S. Economy Billions*, Joint Economic Committee, May 2008 https://www.jec.senate.gov/public/index.cfm/democrats/2008/5/your-flight-has-been-delayed-again_1539

Appendix J. An Illustration of the Value of Speedier E-Commerce Delivery

One indication of the contribution of ASP comes from U.S. retail e-commerce which had sales which were $601.7 billion in 2019.[83] The value of speed can be seen in the charges online retailers impose for different delivery speeds. Delivery charges equal to several percent of the cost of merchandise also can be included in prices of products with free shipping and are in the $119 per year membership charge for Amazon Prime.

Merchandise is more often shipped by air when speedier delivery is required. That can add several percent to overall cost of those packages to which it applies. Packages can travel by multiple modes. BY way of illustration, if the cost of additional reliance on air cargo to achieve speedier delivery equaled an average of ½%-1% of *all* retail e-commerce sales, the value of the added speed would be $3-$6 billion. As noted, airport improvements dependent on ASP validation for 2% or more of all runways. Conservatively assuming only 1% of the benefit of speedier delivery with use of air cargo was made possible by capacity increases requiring ASP services, their value would be $30-$60 million. To the extent this involves domestic flights it is not included in the TRB estimates of the value of connectivity.

[83] U.S. Department of Commerce, Bureau of the Census, "Quarterly Retail E-Commerce Sales, 4th Quarter 2019," *U.S. Census Bureau News*, CB 20-24, February 19, 2020 https://www.census.gov/retail/mrts/www/data/pdf/ec_current.pdf

VIII. Interviews, Discussions and Comments

Name	Affiliation
Mike Aslaksen	Director, NGS Remote Sensing Division,
Ted Doyle	NGS Aeronautical Survey Program
Leo Eldredge	Former Manager, FAA Navigation Programs, Program Management Organization
Gavin Fahnestock	Senior Aviation Planner, Atkins Global
Clifford Feldheim	Senior Geodetic Manager, Quantum Spatial
Benjamin Gottleib	Engineering Consultant, FAA Hughes Technical Center
Monica Grasso	Chief Economist, NOAA
Maureen Green	NGS Chief, Management and Budget
Leeann Hart	Airspace Modernization Management and Program Analyst, FAA
Mark Howard	NGS Aeronautical Survey Technical Lead
Kevin S. Jordan	NGS Observation and Analysis Division
Chris Kerns	NGS Aeronautical Survey Program Director
Scott Lokkin	NGS Regional Geodetic Advisor, Mid-Atlantic; former NGS ASP staff
Adam Lunn	Airport Operations Manager, Lakeland Linder International Airport
Michell Narins	Principal Consultant, Strategic Synergies; former FAA Engineer
Robert Novia	Manager, Airspace Redesign, FAA
Julie Prusky	NGS Observation and Analysis Division
Dez Silagi	FAA Aeronautical Information Services – Oklahoma City
Sherri Watkins	NGS Financial Management Specialist/COR III
Eric Wolfe	Chief Economist, NOAA National Ocean Service

VIII. Abbreviations

3D	three dimensional
AC	FAA Advisory Circular
ACRP	Transportation Research Board Airport Cooperative Research Program
AFTIL	Airways Facilities Tower Integration Laboratory
AGIS	Airport Geographic Information System
AIP	Airport Improvement Program
ASP	Aeronautical Survey Program
BCA	Benefit-Cost Analysis
BGR	Bangor International Airport
BLS	Bureau of Labor Statistics
CAT	category
CDA	continuous descent arrival
CORS	Continuously Operating Reference Stations
DUT/PADU	Unalaska Airport
E5	A European Galileo navigation satellite signal
FAA	Federal Aviation Administration
FMS	Flight Management System
GDP	Gross Domestic Product
GIS	Geographic Information Systems
GNSS	Global Navigation Satellite Systems
GPS	Global Positioning System
GRAV-D	Gravity for the Redefinition of the Vertical Datum
GSA	General Services Administration
IFR	Instrument Flight Rules
L5	A GPS satellite signal
LIDAR	Light Detection and Ranging
LP	Localizer Performance
LPV	Localizer Performance with Vertical Guidance
MHT/KMHT	Manchester Municipal Airport
MOBIS	Mission Oriented Business Integration Services
MSA	Metropolitan statistical area
Navaids	navigation aids
NESTOR	National Center for Excellence for Aviation Operation Research
NGS	National Geodetic Survey
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
NPIAS	National Plan of Integrated Airport Systems
NSRS	National Spatial Reference System

OAD	NGS Observation and Analysis Division
OMB	Office of Management and Budget
OPUS	Online Positioning User Service
PACS	Primary Airport Control System
PBN	Performance-Based Navigation
PDV	present discounted value
RNAV	Area Navigation
RNP	Required Navigation Performance
RPAT	RNP Parallel Approach with Transition
RSD	NGS Remote Sensing Division
SACS	Secondary Airport Control System
TRB	Transportation Research
UDDF	uniform data distribution file
U.S.	United States
VSL	Value of Statistical Life
WAAS	Wide Area Augmentation System

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X. ARCBridge Consulting and Training, Inc.

Since 1994 ARCBridge Consulting and Training has helped clients across the country achieve their mission goals. Capitalizing on over 20 years of experience working with clients in the Law Enforcement, Emergency Management, Homeland Security, Defense, HealthCare, Housing, Agriculture, Transportation, Justice, Census and Local Governments, our highly professional and trained associates have gained years of valuable experience in working closely with our customers to understand their needs and finding the best solutions. Small and agile, ARCBridge continues to enjoy client satisfaction and we strive to keep on the leading edge of Technology and Business Analytics.

Originally founded by two Virginia Tech Graduates, ARCBridge still enjoys full support of the founders in day to day workings of the corporation and they remain in direct contact with our esteemed clients.

- Small, woman-owned business based in the Washington DC Area
- GSA 70 and MOBIS Contracts
- Business Support, Program Evaluation, Geospatial Services

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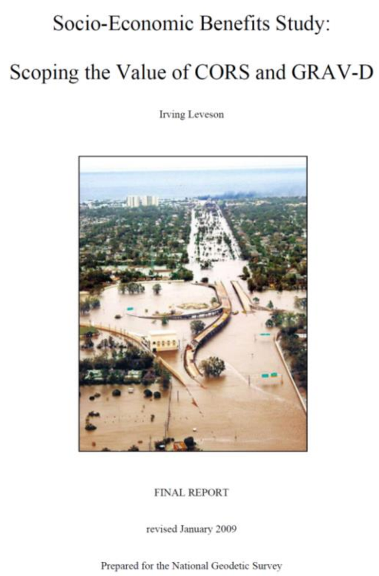
XI. Previous Socio-Economic Studies for NGS

Dr. Leveson previously conducted socio-economic studies of CORS and GRAV-D and the NGS Coastal Shoreline Mapping Program. He was the principal researcher on the 2017 ARCBridge study of the 2019 Socio-economic study of the NGS Regional Geodetic Advisors Program and the 2019 ARC Bridge study of the NGS Gravity Program. The reports and descriptions are online at the following locations:

All NGS economic reports https://geodesy.noaa.gov/INFO/applications-of-geodesy.shtml



Socio-Economic Benefits Study:

Scoping the Value of CORS and GRAV-D

Irving Leveson

FINAL REPORT

revised January 2009

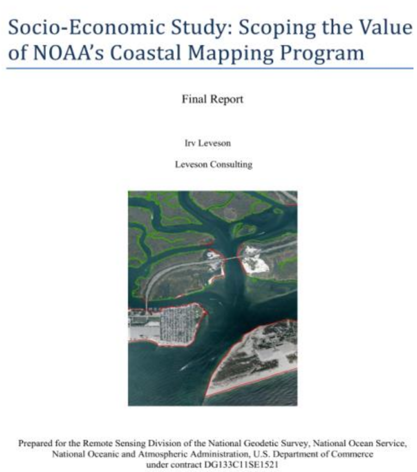
Prepared for the National Geodetic Survey

One-page handout available at:

http://www.ngs.noaa.gov/INFO/OnePagers/socio_eco_handout.pdf

Full study available at:

http://www.ngs.noaa.gov/PUBS_LIB/Socio-EconomicBenefitsofCORSandGRAV-D.pdf



Socio-Economic Study: Scoping the Value of NOAA's Coastal Mapping Program

Final Report

Irv Leveson

Leveson Consulting

Prepared for the Remote Sensing Division of the National Geodetic Survey, National Ocean Service, National Oceanic and Atmospheric Administration, U.S. Department of Commerce under contract DG133C11SE1521

Description available at:
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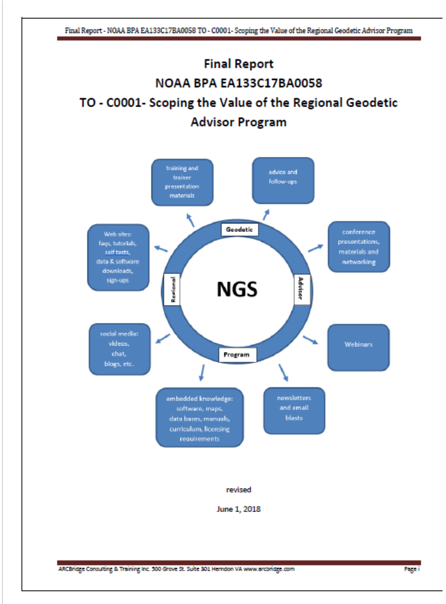
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June 1, 2018

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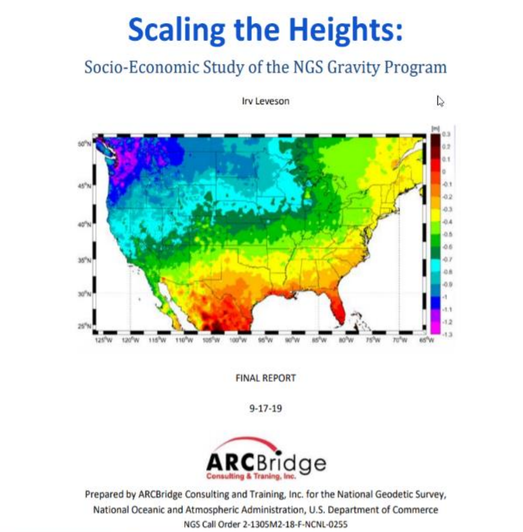
Scaling the Heights:

Socio-Economic Study of the NGS Gravity Program

Irv Leveson

FINAL REPORT

9-17-19

ARCBridge Consulting & Training, Inc.

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NGS Call Order 2-1305M2-18-F-NCNL-0255

Scaling the Heights: Socio-economic Study of the NGS Gravity Program, 2019

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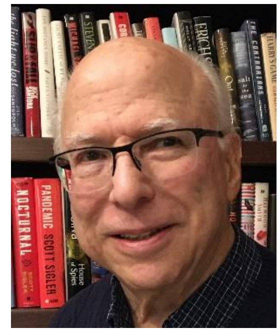
XII. Leveson Bio



Dr. Leveson has strong analytical skills in economics, business and public policy and extensive experience analyzing programs, markets, and technologies. His background includes strategic and economic consulting and research in private industry, non-partisan think tanks, and government. Dr. Leveson has consulted for NOAA and affiliates on a wide range of issues for the last 19 years. This is his fifth study for NGS.

Dr. Leveson holds a Ph.D. in economics from Columbia University. Prior to establishing Leveson Consulting in 1990, he served as Senior Vice President and Director of Research of Hudson Strategy Group, Director of Economic Studies of the Hudson Institute, Assistant Administrator for Health Systems Planning for the New York City Health Services Administration and as a research director for the New York City Planning Commission. He also served as an economist with the RAND Corporation and an analyst with the National Bureau of Economic Research. Dr. Leveson is a member of the Institute of Navigation, the American Meteorological Society, the American Economic Association and the National Association for Business Economics.

His books include *Economic Security*, *American Challenges*, *Western Economies in Transition* (co-ed.), *The Future of the Financial Services Industry* (main author), *Analysis of Urban Health Problems* (co-ed.) and *Quantitative Explorations in Drug Abuse Policy* (ed.).

His work with NOAA has included support to the Chief Economist over a decade, reports on a wide range of subjects, and assistance in applying social science to issues and programs through workshops and educational materials. Recent work has included examining programs of the National Geodetic Survey, analyzing markets, applications, and benefits of GPS, and assessing applications and benefits of data from GOES weather satellites and risks from spectrum interference.