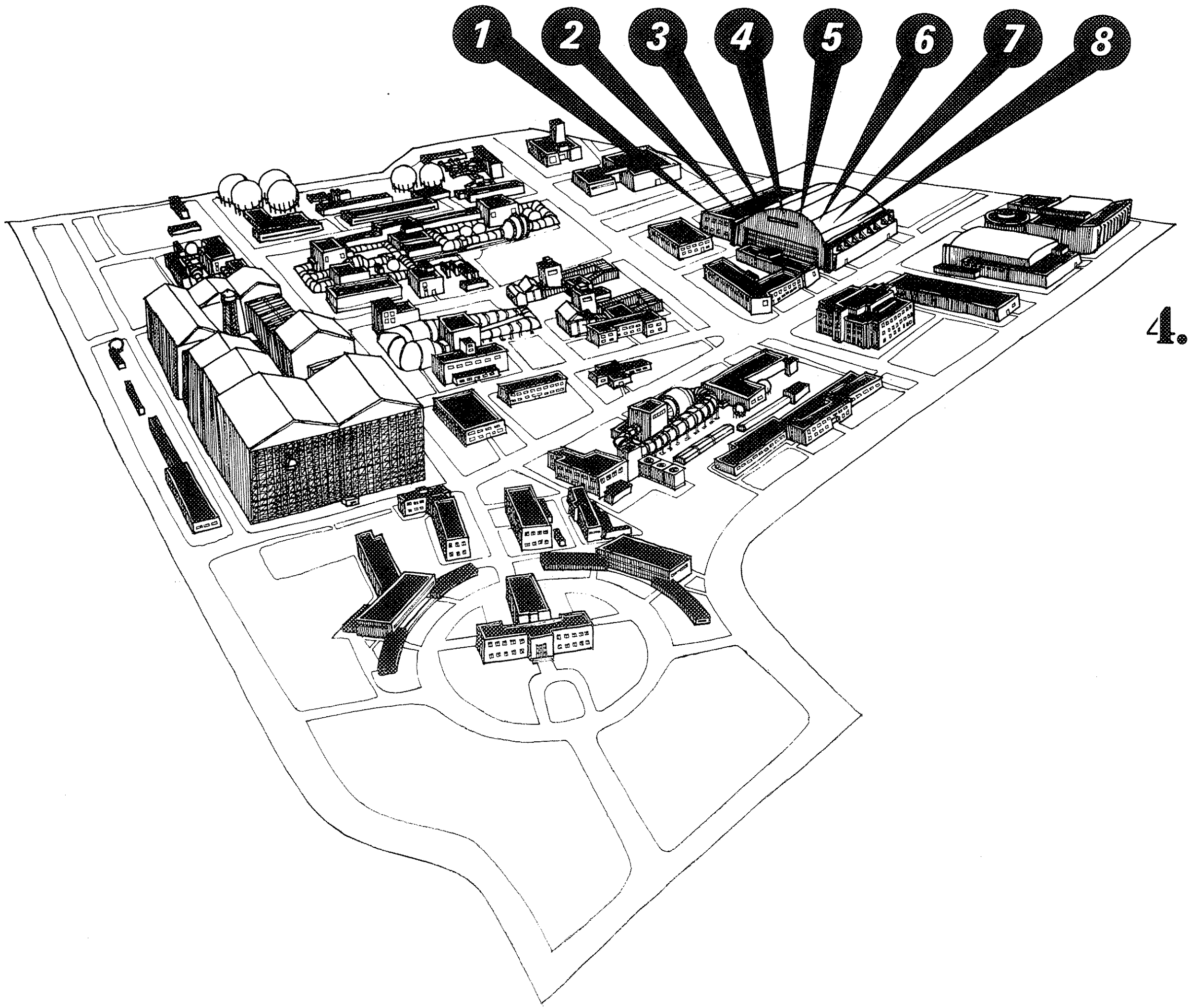
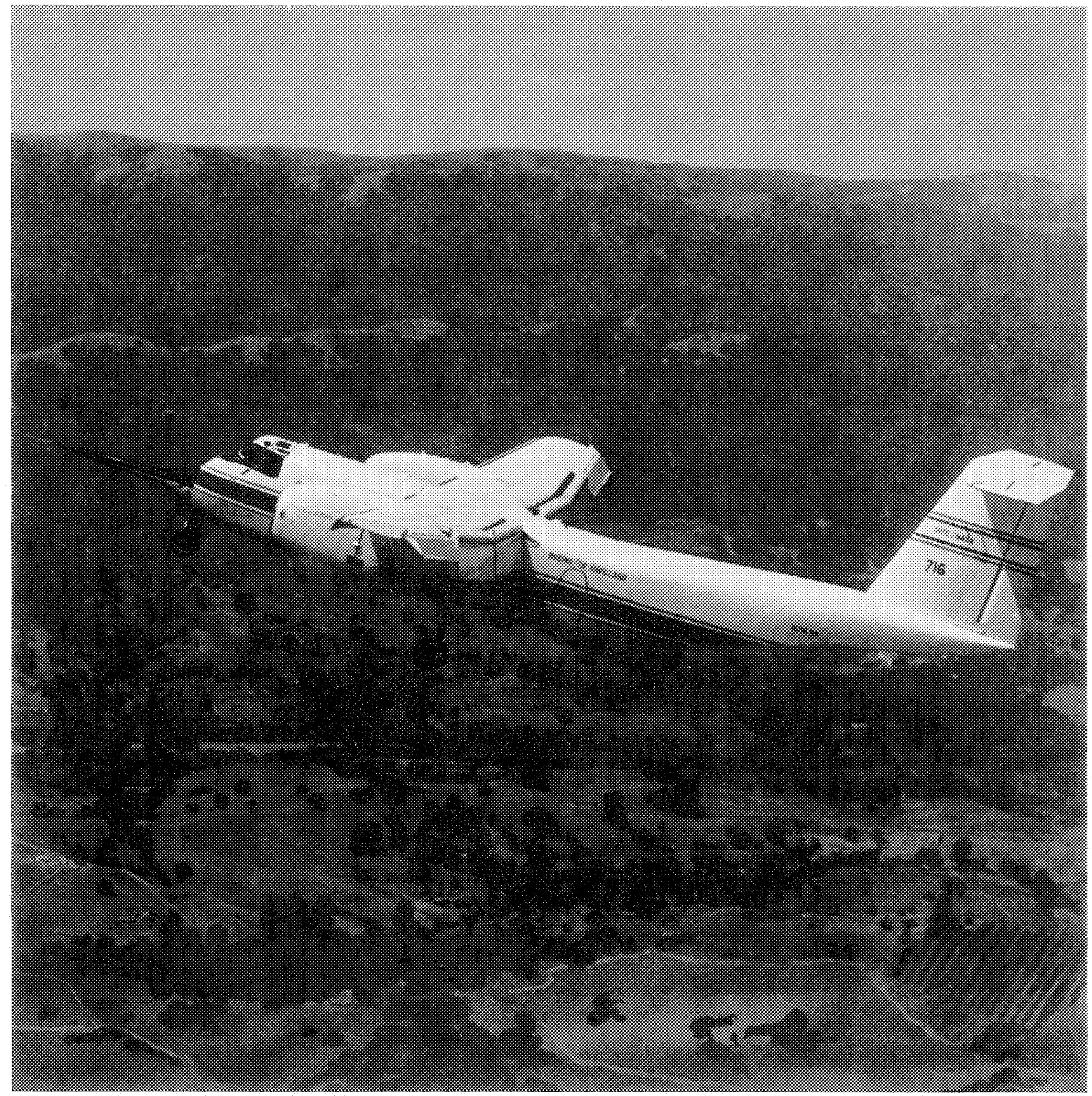


4. RESEARCH AIRCRAFT

1. *C8-A BUFFALO AUGMENTOR WING JET-STOL AIRCRAFT*
2. *CV-340 FLYING LABORATORY*
3. *X-14B VTOL RESEARCH AIRCRAFT*
4. *LEAR 23 AND 24B AIRCRAFT*
5. *CV-990A AIRBORNE RESEARCH LABORATORY*
6. *C-141A AIRBORNE INFRARED OBSERVATORY*
7. *EARTH RESOURCES SURVEY AIRCRAFT*
8. *YOV-10A STOL RESEARCH AIRCRAFT*

4. RESEARCH AIRCRAFT

1. C8-A BUFFALO AUGMENTOR WING JET-STOL AIRCRAFT



DESCRIPTION:

The C8-A Buffalo Augmentor Wing Jet-STOL research aircraft is a modified version of a high-wing, high-tail turboprop Buffalo military transport manufactured by the deHavilland, Ltd., of Canada, and designated NASA 716. It is used to study the design and operational characteristics of jet-STOL aircraft using split-flow turbofan engines to provide both propulsive and augmentor wing jet flows for increased powered-lift. Major modifications to the aircraft include: a) wing span reduced from 96 to 78.8 ft., b) augmentor flap system (including augmentor chokes), c) drooped aileron with boundary layer control, d) repositioned and redesigned spoilers, e) fixed, full-span leading-edge slats, f) T-64 turboprop engines replaced with Rolls Royce Spey split-flow turbofan engines, g) an air distribution duct system to supply fan air to the augmentor flaps, fuselage blowing, and aileron, h) lateral directional stability augmentation system (SAS), i) increased-capacity hydraulic system, and j) extensive flight test instrumentation. This aircraft has a practical operating range of about 300 nautical miles at 160 knots indicated air speed, an operating ceiling of about 15,000 ft., and a useful payload of 2,290 lbs. The modified C8-A Buffalo is being flight tested as part of the augmentor wing jet STOL research program being conducted jointly by NASA and the Canadian Department of Industry, Trade, and Commerce (DITC).

PERFORMANCE:

STOL takeoff weight	45,000 lbs, max.
Basic weight (less fuel and payload)	32,200 lbs
Fuel weight	14,800 lbs
Takeoff distance	$<$1,500 ft
Landing distance	$<$1,500 ft

STATUS:

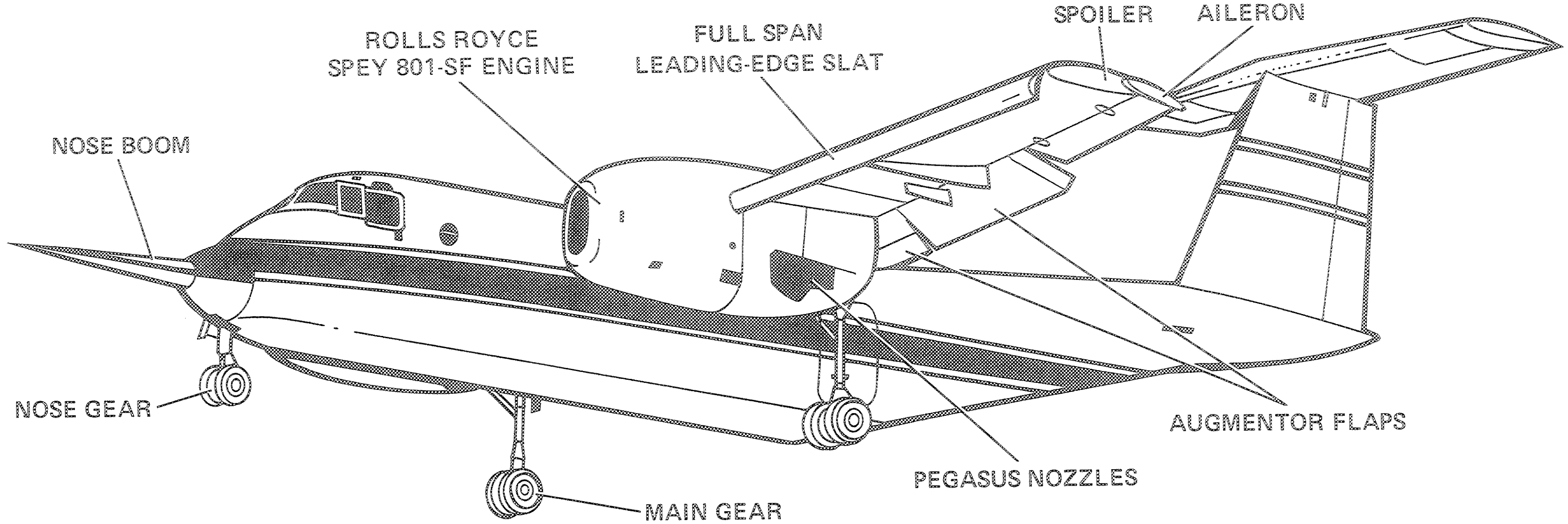
Operational since 1972

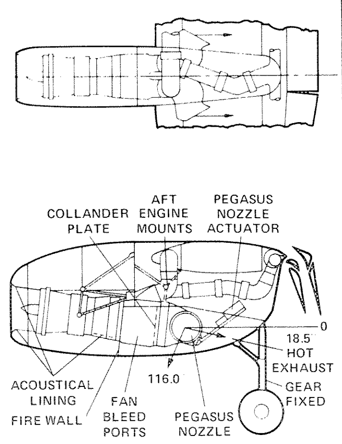
JURISDICTION:

V/STOL Projects Office
Hervey C. Quigley

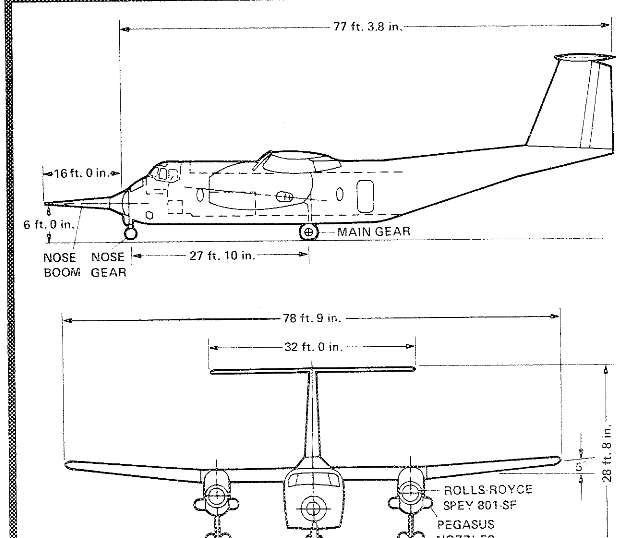
LOCATION:

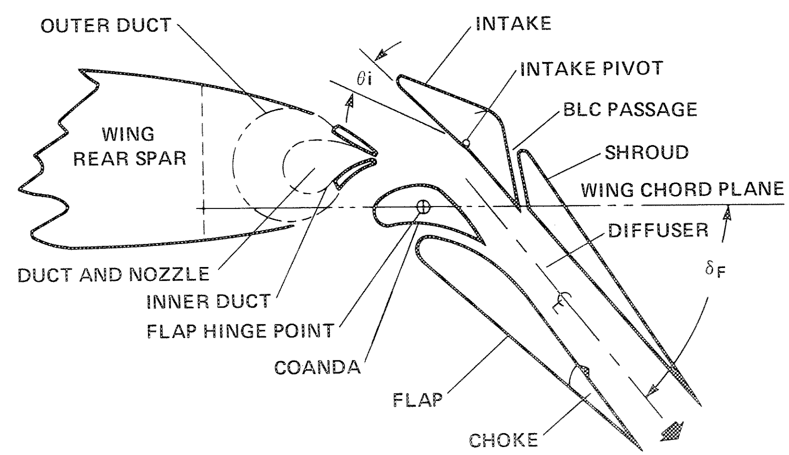
Building N-211





PROPULSION NACELLE





SCHEMATIC OF AUGMENTOR FLAP SYSTEM

2. CV-340 FLYING LABORATORY

DESCRIPTION:

The CV-340 Flying Laboratory is a modified, two engine, low-wing monoplane manufactured by the Convair/General Dyanmics Corporation, and designated NASA 707. It is used for aeronautics research, primarily in support of navigation, guidance and control studies, as well as avionics systems and cockpit display concepts for STOL operations. It has a practical operating range of about 1,000 nautical miles at 210 knots indicated air speed, an operating ceiling of about 20,000 ft., and a useful payload of 6,000 lbs. This aircraft is of all-metal construction, with full cantilever wings, tricycle landing gear, and a conventional, single vertical tail unit. The fuselage is semi-monocoque, pressurized, with passengers (normally 8) above and cargo below. It is equipped with a portable aircraft range measuring system (DMS), a modified Scientific Data System 920 general-purpose digital computer, three CRT-type display units, and 12 strip-chart recorders. The aircraft is supplied power for its standard equipment from engine-driven generators and inverters. Power used for all experimental equipment is supplied from a 14KW gas turbine power plant located in the aft section of the aircraft.

PERFORMANCE:

Takeoff weight	47,000 lbs, max.
Basic weight (less fuel and payload)	36,000 lbs
Fuel weight	10,000 lbs
Takeoff distance	4,000 ft
Landing distance	4,000 ft

STATUS:

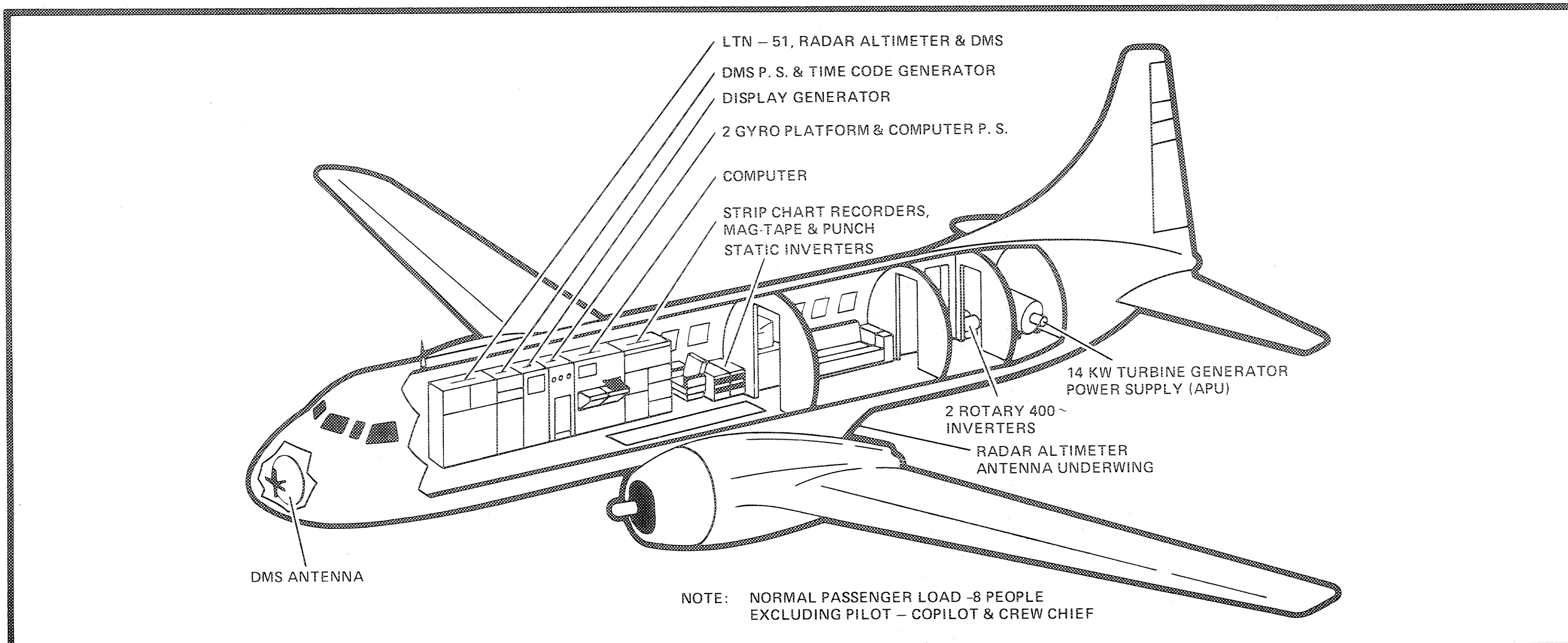
Operational since 1964, refurbished 1973.

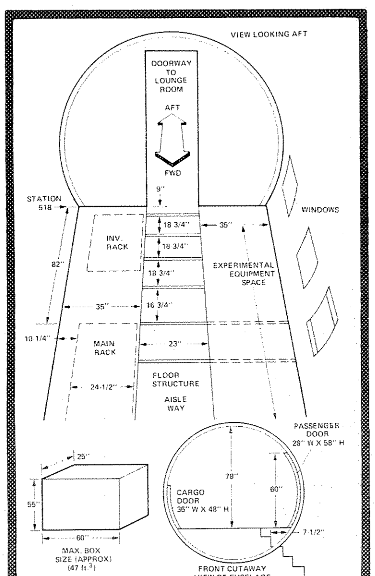
JURISDICTION:

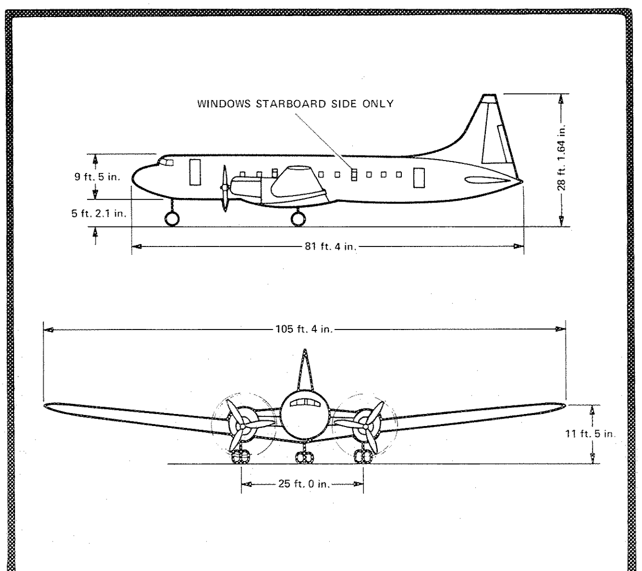
Flight Systems Research Division
Avionics Research Branch
Henry C. Lessing

LOCATION:

Building N-211


LTN – 51, RADAR ALTIMETER & DMS
DMS P. S. & TIME CODE GENERATOR
DISPLAY GENERATOR
2 GYRO PLATFORM & COMPUTER P. S.
COMPUTER
STRIP CHART RECORDERS, MAG-TAPE & PUNCH
STATIC INVERTERS
14 KW TURBINE GENERATOR POWER SUPPLY (APU)
2 ROTARY 400~ INVERTERS
RADAR ALTIMETER ANTENNA UNDERWING
DMS ANTENNA
NOTE: NORMAL PASSENGER LOAD -8 PEOPLE EXCLUDING PILOT – COPILOT & CREW CHIEF


VIEW LOOKING AFT
DOORWAY TO LOUNGE ROOM
AFT
FWD
STATION 518
INV. RACK
MAIN RACK
EXPERIMENTAL EQUIPMENT SPACE
FLOOR STRUCTURE
AISLE WAY
WINDOWS
PASSENGER DOOR 28" W X 58" H
CARGO DOOR 35" W X 48" H
FRONT CUTAWAY VIEW OF FUSELAGE
MAX. BOX SIZE (APPROX) (47 ft³)


WINDOWS STARBOARD SIDE ONLY
9 ft. 5 in.
5 ft. 2.1 in.
81 ft. 4 in.
28 ft. 1.64 in.
105 ft. 4 in.
11 ft. 5 in.
25 ft. 0 in.

3. X-14B VTOL RESEARCH AIRCRAFT

DESCRIPTION:

The X-14B VTOL Research Aircraft is a variable-stability, variable-control single-place aircraft manufactured by the Bell Corporation, and designated NASA 704. It is a fixed-wing aircraft that has twin engines equipped with cascade-type diverters to vector the jets for any combination of vertical lift or forward thrust. Hovering time is limited to 15 minutes; normal cruise flight time is limited to 20 minutes in normal flight at 120 knots indicated air speed. This aircraft incorporates a unique control and stabilization system known as a model reference (model-following) system. This type of system, which uses an onboard digital computer, permits the synthesis of a wide range of VTOL control systems. It provides the capability for the verification and extension of handling qualities research obtained using ground-based simulators, the comparison of various "optimal" methods of establishing gains for the model following system, and the evaluation of the effectiveness of model following reference systems in minimizing the aircraft's response to external disturbances. This research program is jointly supported by the U.S. Army and NASA.

PERFORMANCE:

Takeoff weight	4,217 lbs, max.
Basic weight (less fuel and payload)	3,470 lbs
Fuel weight (100 gals.)	620 lbs
Takeoff distance (conventional)	~1,000 ft
Landing distance (conventional)	~1,000 ft

STATUS:

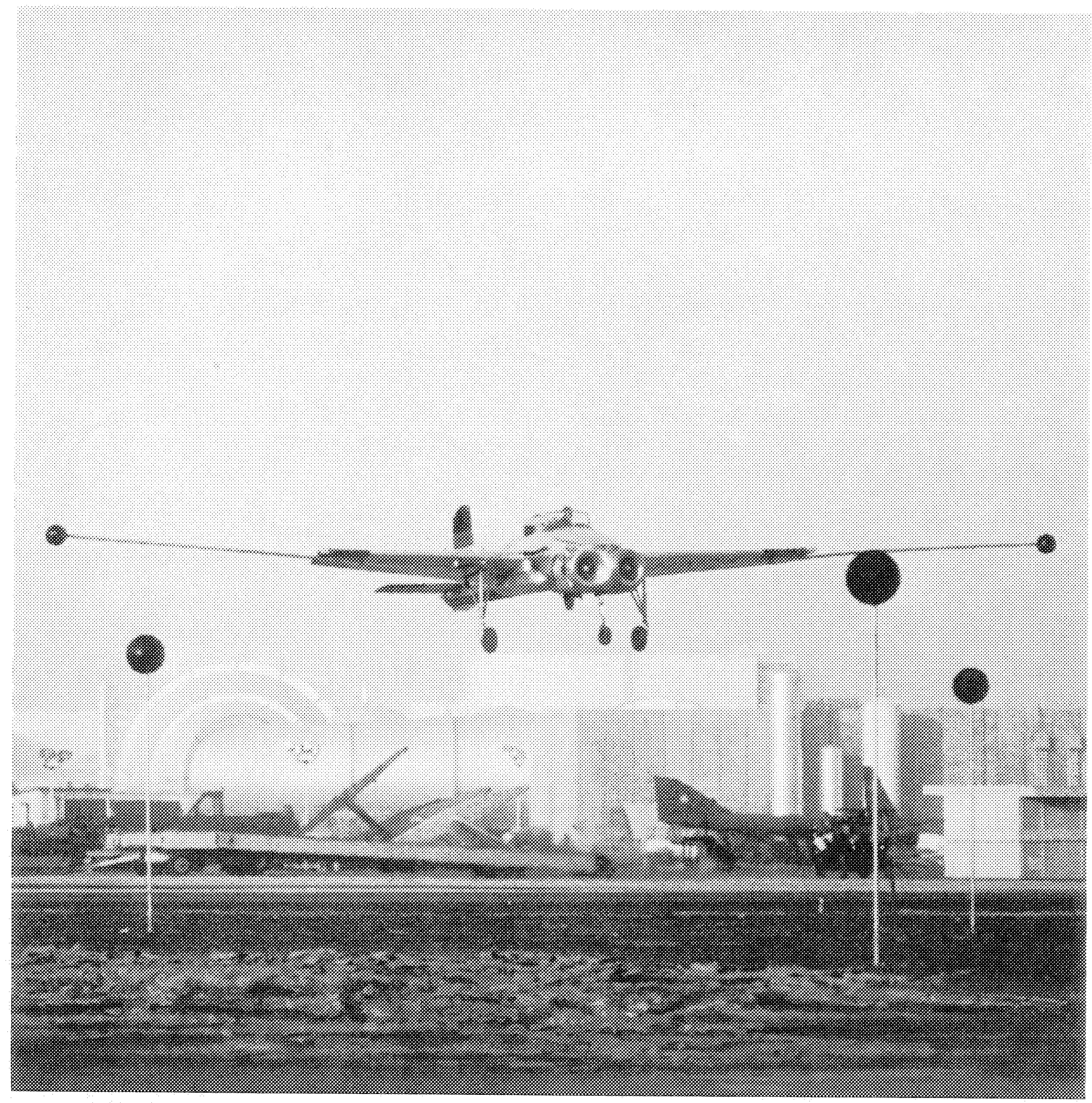
Operational since 1971

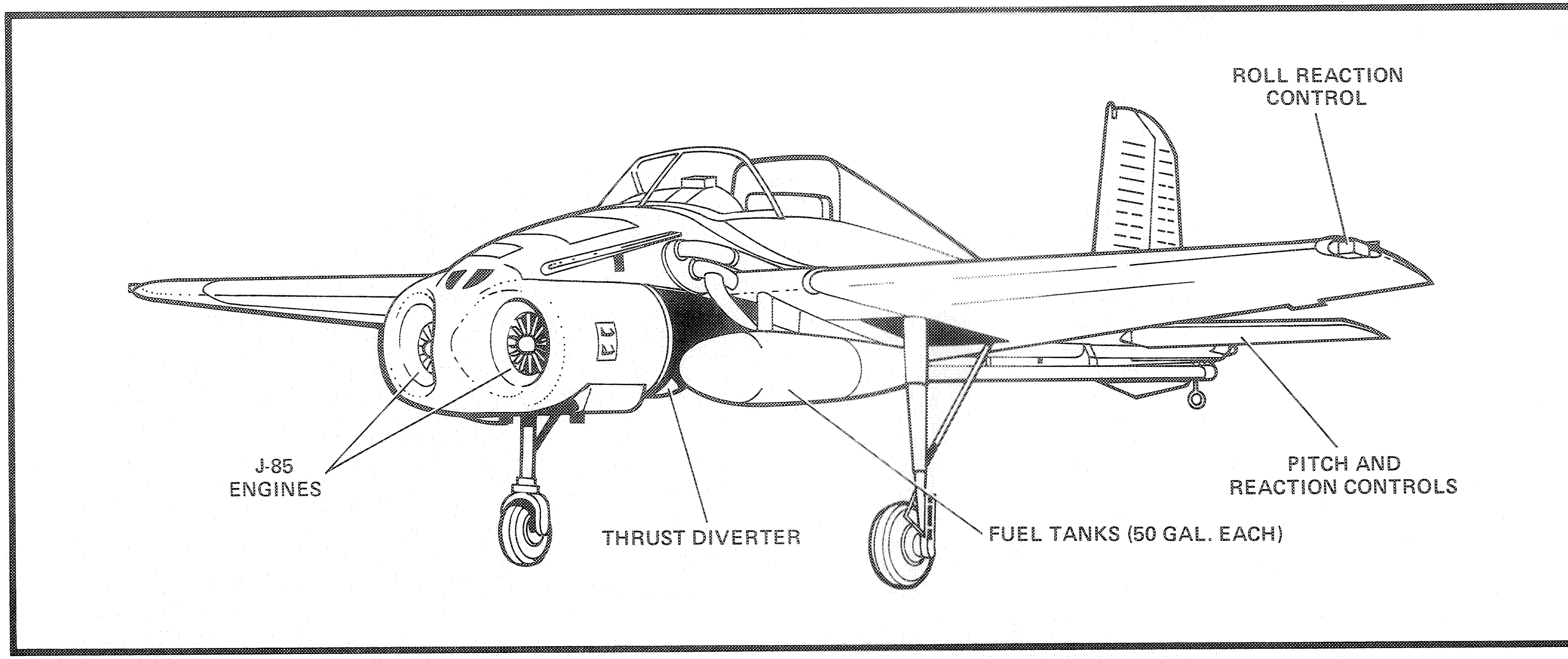
JURISDICTION:

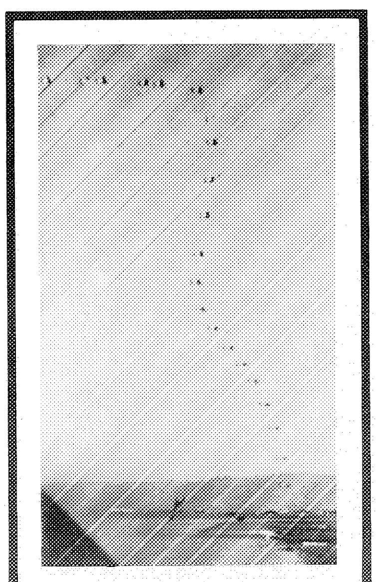
Flight Systems Research Division
Flight and Systems Research Branch
Maurice D. White

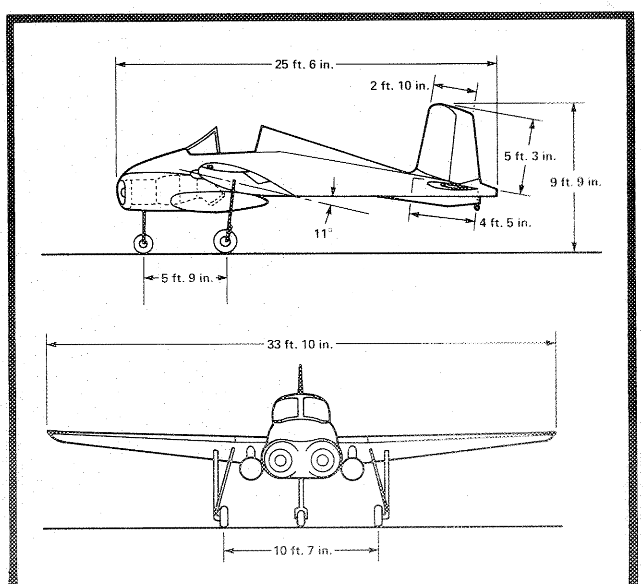
LOCATION:

Building N-211




ROLL REACTION
CONTROL
J-85
ENGINES
THRUST DIVERTER
FUEL TANKS (50 GAL. EACH)
PITCH AND
REACTION CONTROLS




25 ft. 6 in.
2 ft. 10 in.
5 ft. 3 in.
9 ft. 9 in.
4 ft. 5 in.
11°
5 ft. 9 in.
33 ft. 10 in.
10 ft. 7 in.

4. LEAR 23 AND 24B AIRCRAFT

DESCRIPTION:

The Lear 23 and 24B aircraft are modified, twin-engine executive jets manufactured by the Gates Learjet Corporation, and designated NASA 701 and 265-EJ, respectively. These aircraft are used primarily for aeronautical research and as high-altitude observation platforms. They have a practical operating range of about 2,000 nautical miles at 470 knots indicated air speed, an operating ceiling of about 45,000 ft., and a useful payload of 1,000 lbs. They are of all-metal construction, with conventional tricycle landing gear, and a T-tail unit. The fuselage is semi-monocoque, pressurized, with a two-piece, three-foot wide door on the left side of the cabin.

The Lear 265-EJ has been modified with two special hatches (which replace the starboard, over-wing emergency exit hatch) for upward viewing. Each hatch has a maximum circular clear aperture of 37.6 cm. A gyrostabilized mirror providing a line-of-sight stability of better than 10 arc sec rms is available for astronomical or geophysical experiments. In addition to the special hatch, there is one 61.0 cm long by 43.2 cm high plexiglass window on each side of the cabin.

PERFORMANCE:

Takeoff weight	13,500 lbs, max.
Basic weight (less fuel and payload)	6,851 lbs
Fuel weight (840 gals.)	5,628 lbs
Takeoff distance	2,866 ft
Landing distance	2,016 ft

STATUS:

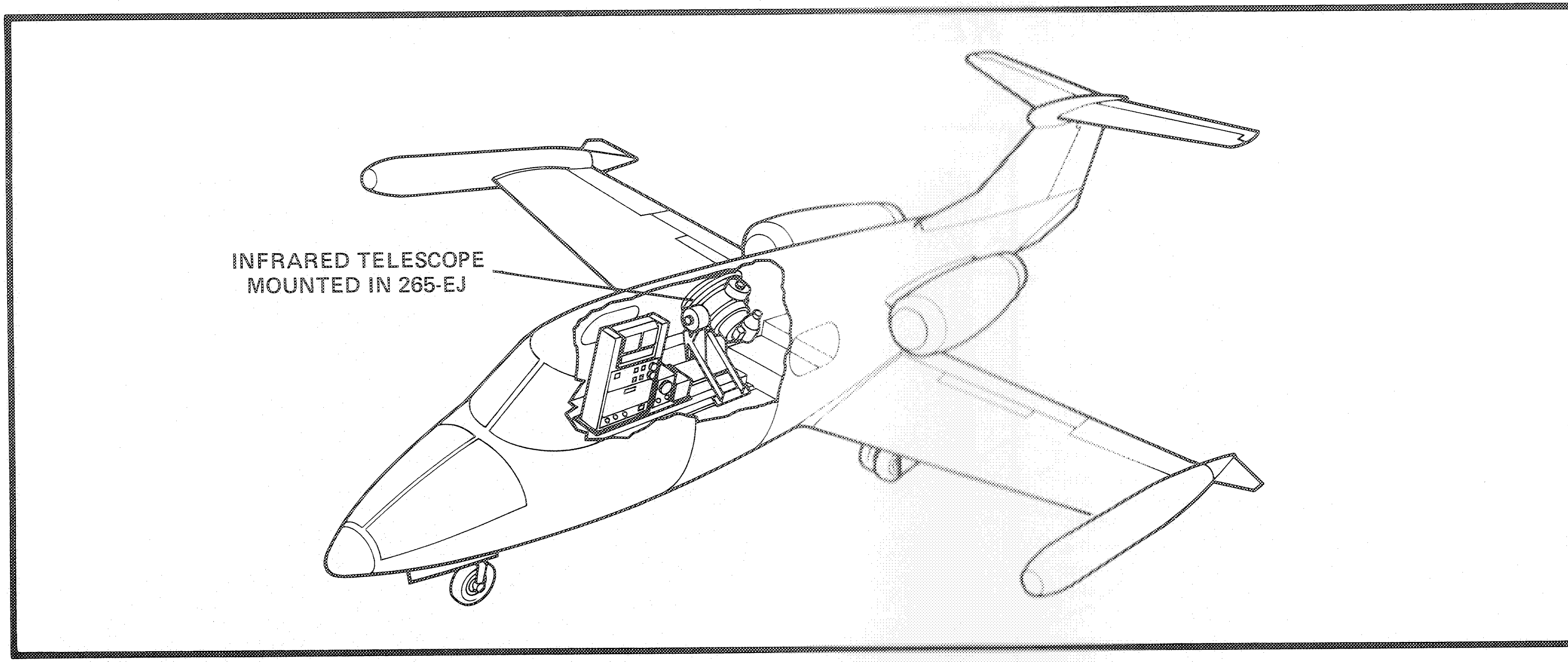
Operational since 1965, 1973

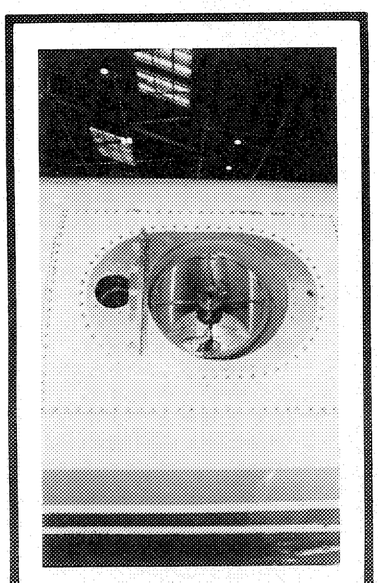
JURISDICTION:

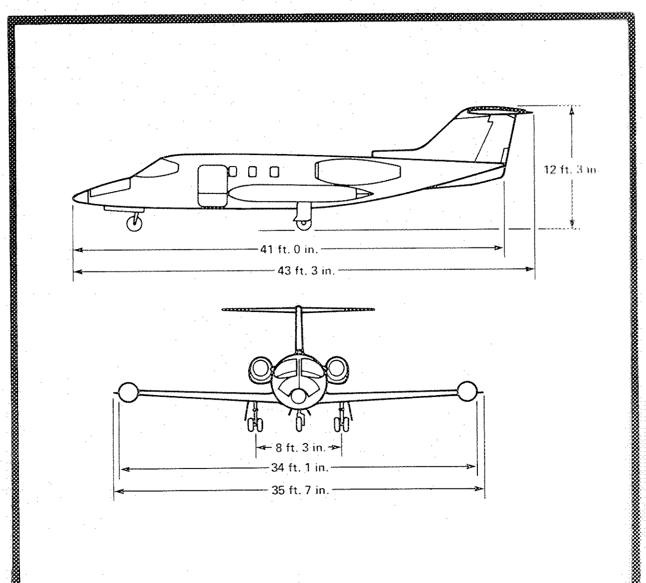
265-EJ	NASA 701
Space Science Division	Flight Systems Research Division
Airborne Sciences Office	Flight Operations Branch
Donald R. Mulholland	George E. Cooper

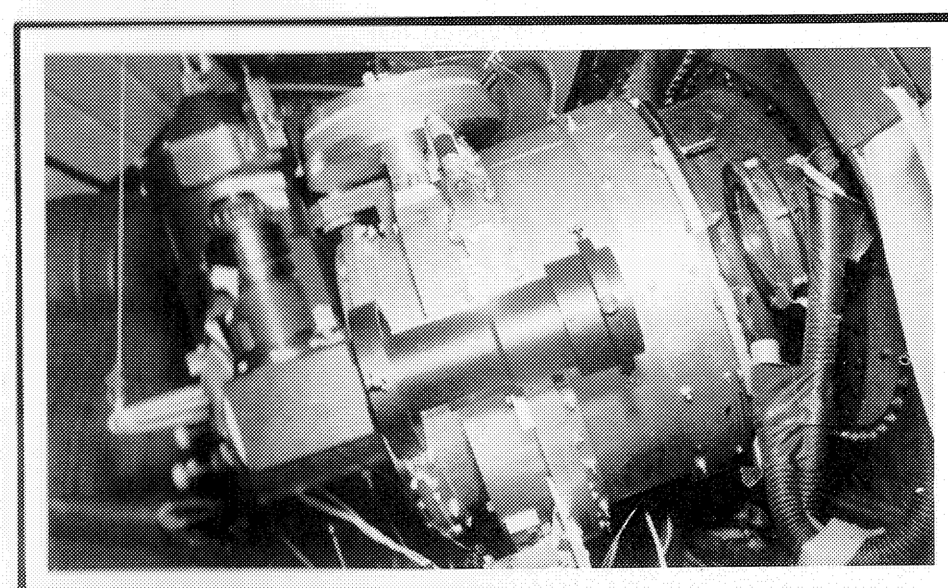
LOCATION:

Building N-211


INFRARED TELESCOPE
MOUNTED IN 265-EJ




12 ft. 3 in.
41 ft. 0 in.
43 ft. 3 in.
8 ft. 3 in.
34 ft. 1 in.
35 ft. 7 in.



5. CV-990A AIRBORNE RESEARCH LABORATORY

DESCRIPTION:

The CV-990A Airborne Research Laboratory is a modified, four-engine turbojet, low-wing, 44-seat commercial transport aircraft manufactured by the Convair/General Dynamics Corporation, and designated NASA 712. It is a multi-purpose airplane used both for space science investigations, and aeronautics (operational) research. It has a practical operating range of about 3,300 nautical miles at 350 knots indicated air speed, an operating ceiling of about 41,000 ft., and a useful payload of 20,000 lbs. This aircraft is of all-metal construction with full cantilever wings, retractable tricycle landing gear, and a conventional, single, vertical tail unit. The fuselage is semi-monocoque, pressurized, with passengers above and cargo below. It is equipped with an externally mounted solar sensor and periscoptic sextant. Two zenith and six nadir windows (equipped with hand crank, external shutters) have been installed complete with optical glass, defrosting systems, and safety features. There are also 13 viewports at 65° elevation on port side of the aircraft. The aircraft is equipped with a digital data acquisition system for recording and displaying various flight parameters and experimental data. It is also equipped with a Doppler Computer Controller as part of its navigation computer system.

PERFORMANCE:

Takeoff weight	240,000 lbs, max.
Basic weight (less fuel and payload)	119,000 lbs
Fuel weight	100,000 lbs
Takeoff distance	6,750 ft
Landing distance	4,050 ft

STATUS:

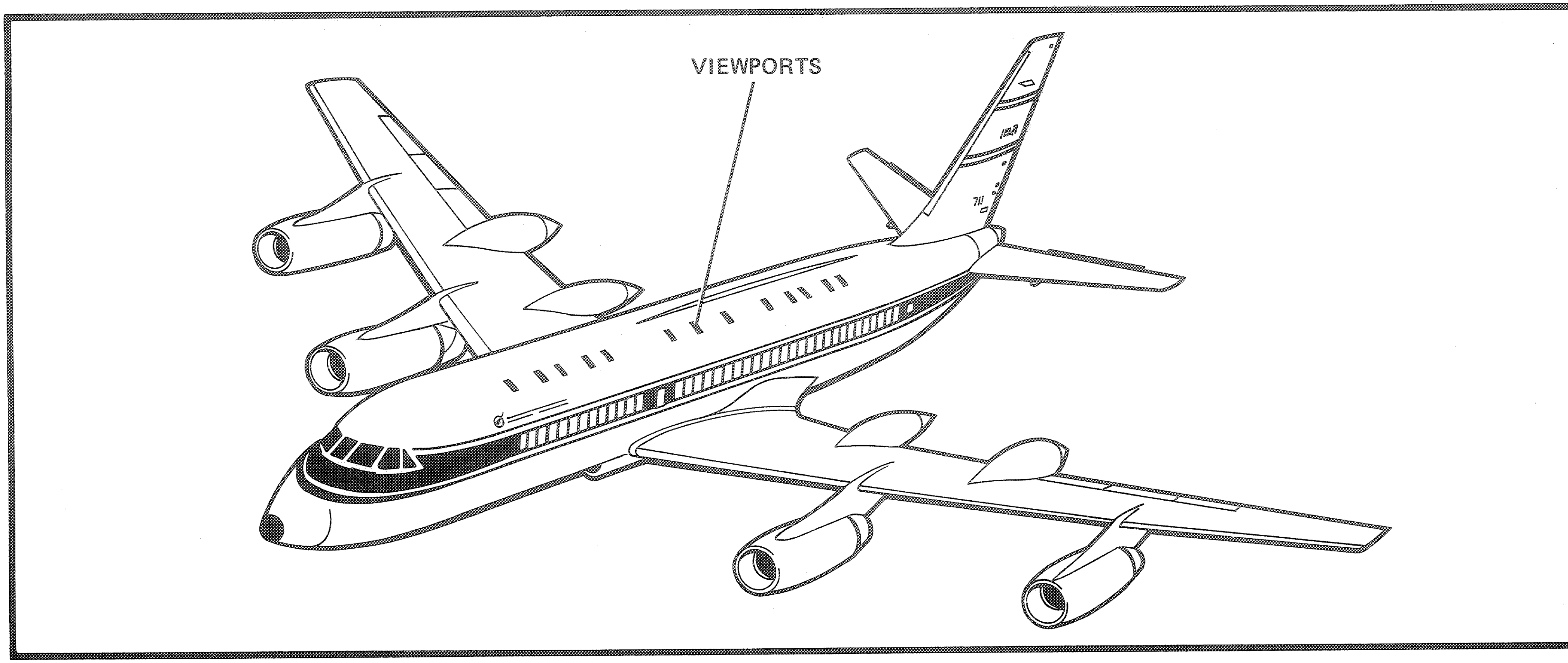
Operational 1973
(NASA 711, operational since 1964, destroyed in mid-air accident April 12, 1973)

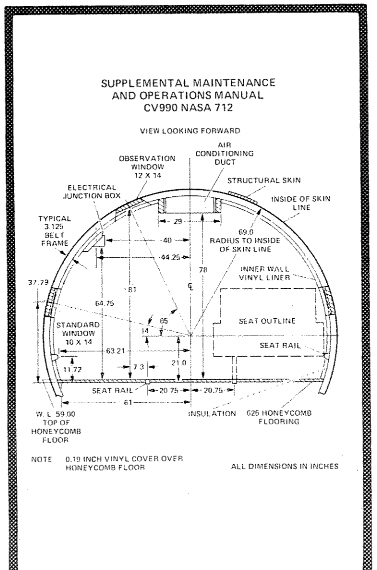
JURISDICTION:

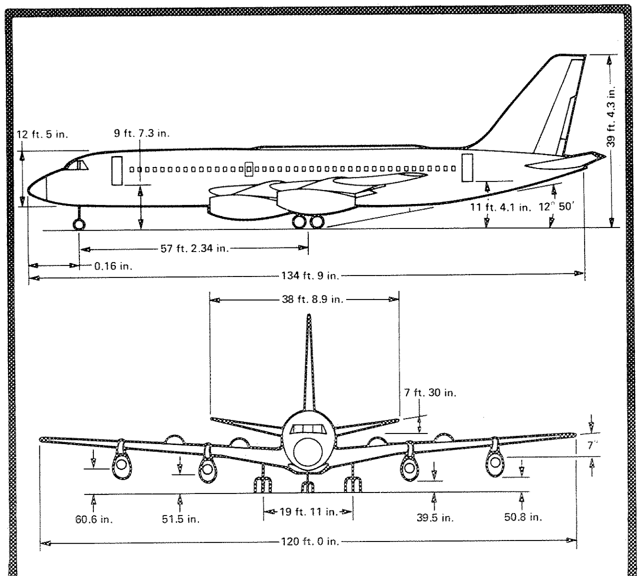
Space Science Division
Airborne Science Office
Donald R. Mulholland

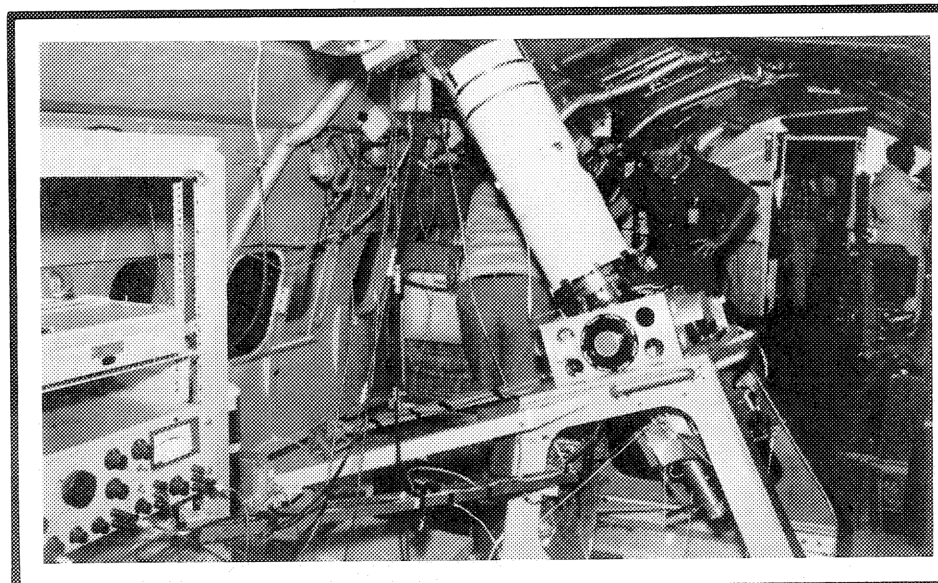
LOCATION:

Building N-211


VIEWPORTS


SUPPLEMENTAL MAINTENANCE
AND OPERATIONS MANUAL
CV990 NASA 712
VIEW LOOKING FORWARD
OBSERVATION WINDOW 12 X 14
AIR CONDITIONING DUCT
STRUCTURAL SKIN
ELECTRICAL JUNCTION BOX
INSIDE OF SKIN LINE
TYPICAL 3.125 BELT FRAME
69.0 RADIUS TO INSIDE OF SKIN LINE
INNER WALL VINYL LINER
SEAT OUTLINE
SEAT RAIL
STANDARD WINDOW 10 X 14
W. L. 59.00 TOP OF HONEYCOMB FLOOR
INSULATION
.625 HONEYCOMB FLOORING
NOTE 0.19 INCH VINYL COVER OVER HONEYCOMB FLOOR
ALL DIMENSIONS IN INCHES


12 ft. 5 in.
9 ft. 7.3 in.
39 ft. 4.3 in.
11 ft. 4.1 in.
12° 50'
57 ft. 2.34 in.
0.16 in.
134 ft. 9 in.
38 ft. 8.9 in.
7 ft. 30 in.
7°
60.6 in.
51.5 in.
19 ft. 11 in.
39.5 in.
50.8 in.
120 ft. 0 in.



6. C-141A AIRBORNE INFRARED OBSERVATORY

DESCRIPTION:

The C-141A Airborne Infrared Observatory is a modified, four engine, high-swept-wing, heavy logistics transport manufactured by the Lockheed Aircraft Corporation, and designated NASA 714. This aircraft is primarily used for space science investigations and infrared astronomy. It has a practical operating range of about 5,200 nautical miles at 440 knots indicated air speed, an operating ceiling of about 45,000 ft., and a useful payload of 70,000 lbs. It is of all-metal construction, with retractable tricycle landing gear, and a T-tail unit. The fuselage is semi-monocoque, pressurized, with an aft cargo ramp.

A 91.5 cm aperture, cassegrain telescope has been installed in the aircraft. It is used for infrared and submillimeter observations. The main optics are totally reflecting, and aerodynamic boundary layer control permits "open-port" operation (no material window). Elevation is adjustable in flight between 35° and 75°. An air bearing support with inertial stabilization and star tracking permits a net line-of-sight stability of better than 2 sec of arc rms in the open port mode. With three, gold-flashed mirrors, the threshold visual magnitude at the cabin-side focus is $m_v = 12$.

PERFORMANCE:

Takeoff weight	315,000 lbs, max.
Basic weight (less fuel and payload)	160,000 lbs
Fuel Weight	153,352 lbs
Takeoff distance	5,100 ft
Landing distance	2,200 ft

STATUS:

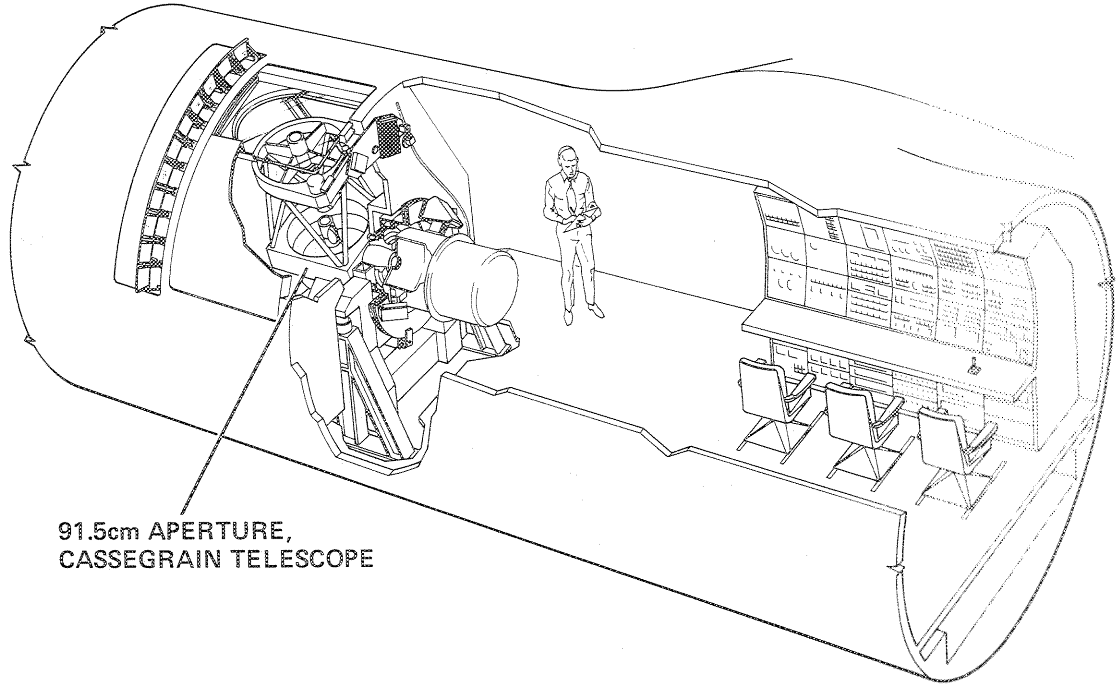
Operational since 1973

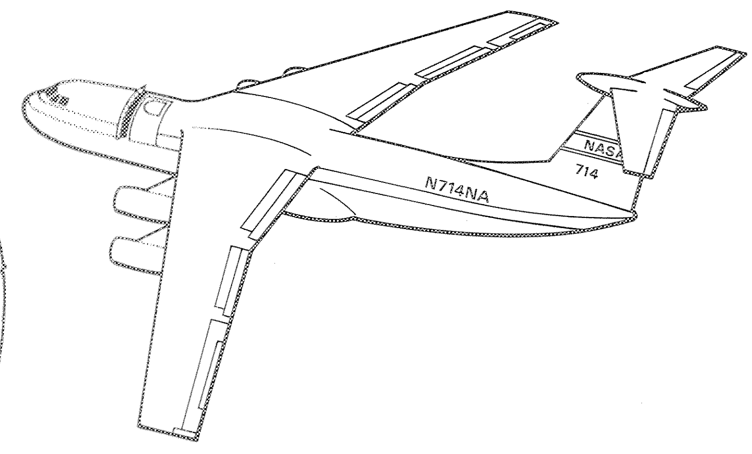
JURISDICTION:

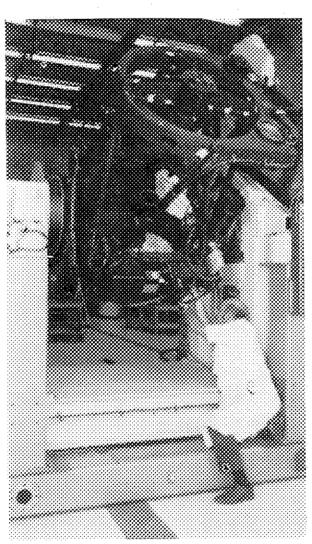
Space Science Division
Airborne Sciences Office
Donald R. Mulholland

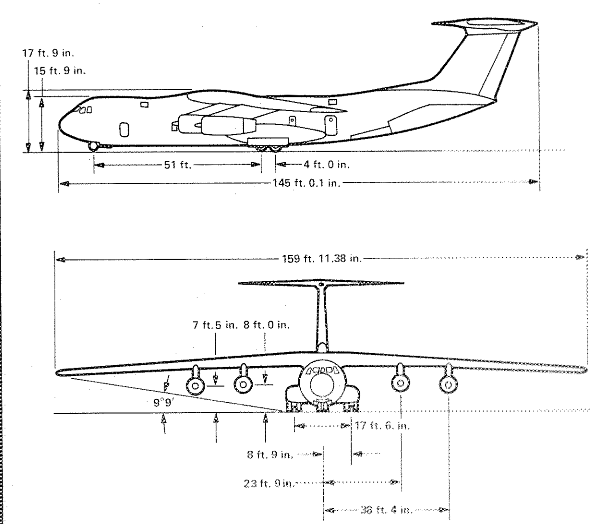
LOCATION:

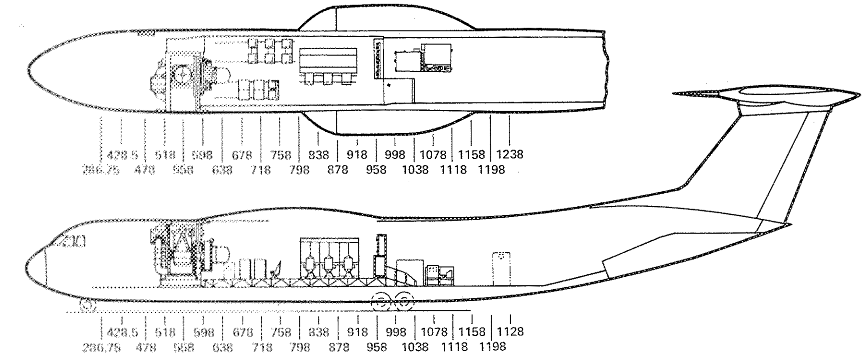
Building N-211


91.5cm APERTURE,
CASSEGRAIN TELESCOPE


NASA
714
N714NA




17 ft. 9 in.
15 ft. 9 in.
51 ft.
4 ft. 0 in.
145 ft. 0.1 in.
159 ft. 11.38 in.
7 ft. 5 in.
8 ft. 0 in.
9°9'
17 ft. 6. in.
8 ft. 9 in.
23 ft. 9 in.
38 ft. 4 in.


428.5 518 598 678 758 838 918 998 1078 1158 1238
286.75 478 558 638 718 798 878 958 1038 1118 1198
428.5 518 598 678 758 838 918 998 1078 1158 1128
286.75 478 558 638 718 798 878 958 1038 1118 1198

7. EARTH RESOURCES SURVEY AIRCRAFT

DESCRIPTION:

Two, high altitude U-2 aircraft, manufactured by the Lockheed Aircraft Corporation, and designated NASA 708 and 709, are based at Ames Research Center. They are primarily used for Earth Resources Survey investigations, as well as astronomical, meteorological, and geophysical experiments. They are single-place aircraft with a practical operating range of about 2,500 nautical miles at Mach 0.69, an operating ceiling of about 65,000 feet, and a useful equipment bay payload of 460 lbs. They are of all metal construction, and each is powered by a single, 15-stage jet engine. These aircraft are characterized by their long wings, two wheel bicycle landing gear and droppable auxiliary gear (pogos) located outboard under each wing. A special equipment bay, located just aft of the cockpit, is the principal location for special equipment packages, such as the Vinten Multi-Spectral Photo Imagery System used for Earth Resources Survey work, which consists of four 70 mm cameras pointed at nadir and synchronized to take simultaneous exposures in four spectral ranges, including the infrared.

PERFORMANCE:

Takeoff weight	22,542 lbs, max.
Basic weight (less fuel and payload)	13,397 lbs
Fuel weight (1,320 gal.)	8,685 lbs
Takeoff distance	1,300 ft
Landing distance (without chute)	4,335 ft

STATUS:

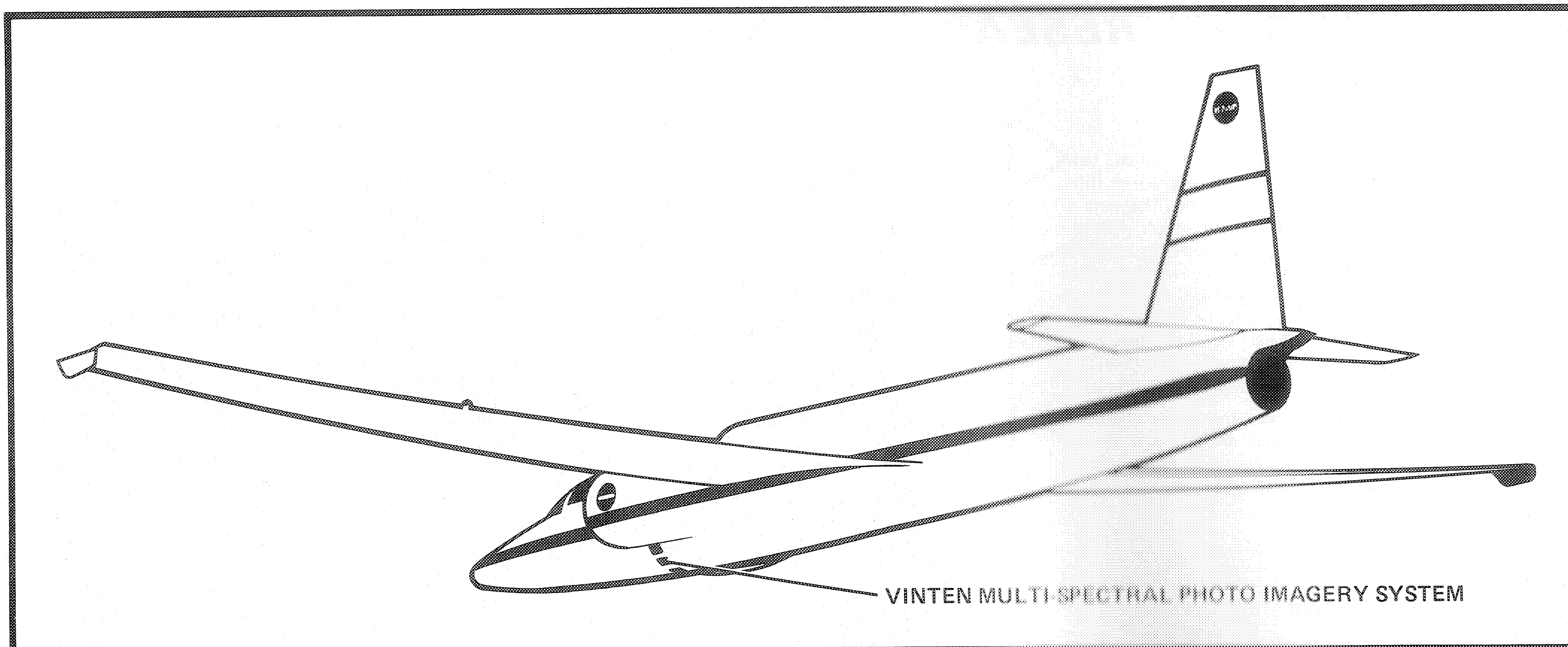
Operational since 1971

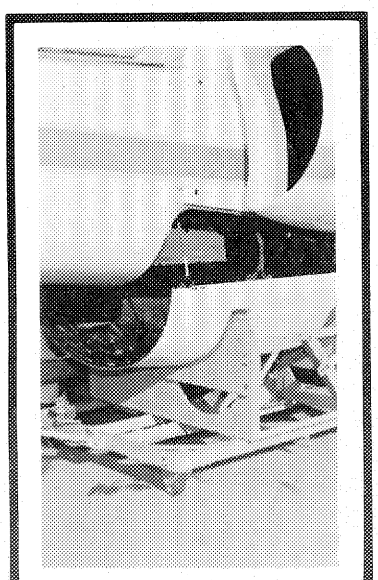
JURISDICTION:

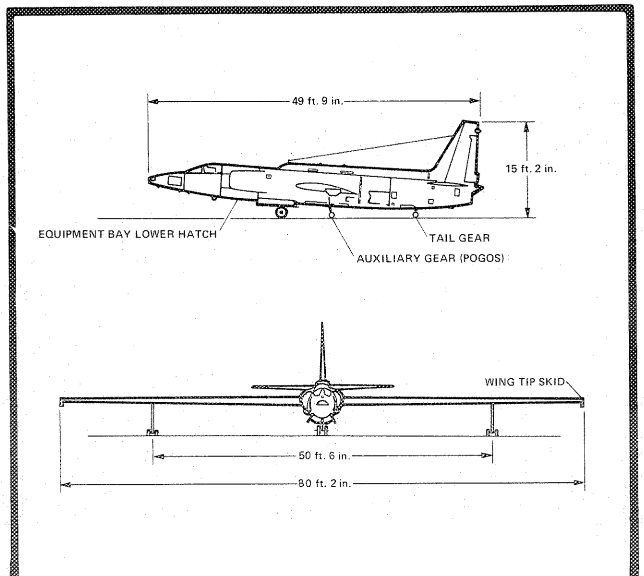
Space Science Division
Airborne Science Office
Donald R. Mulholland

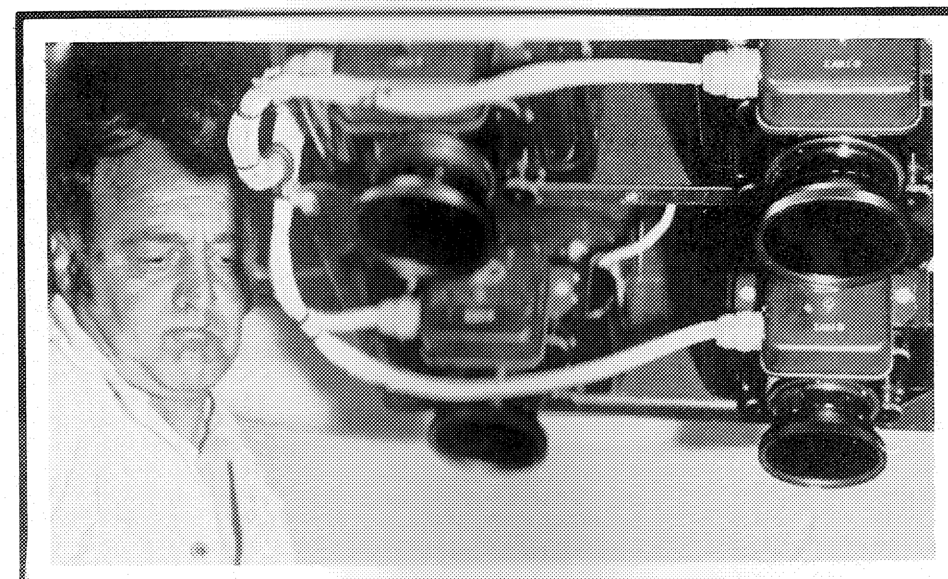
LOCATION:

Building N-211

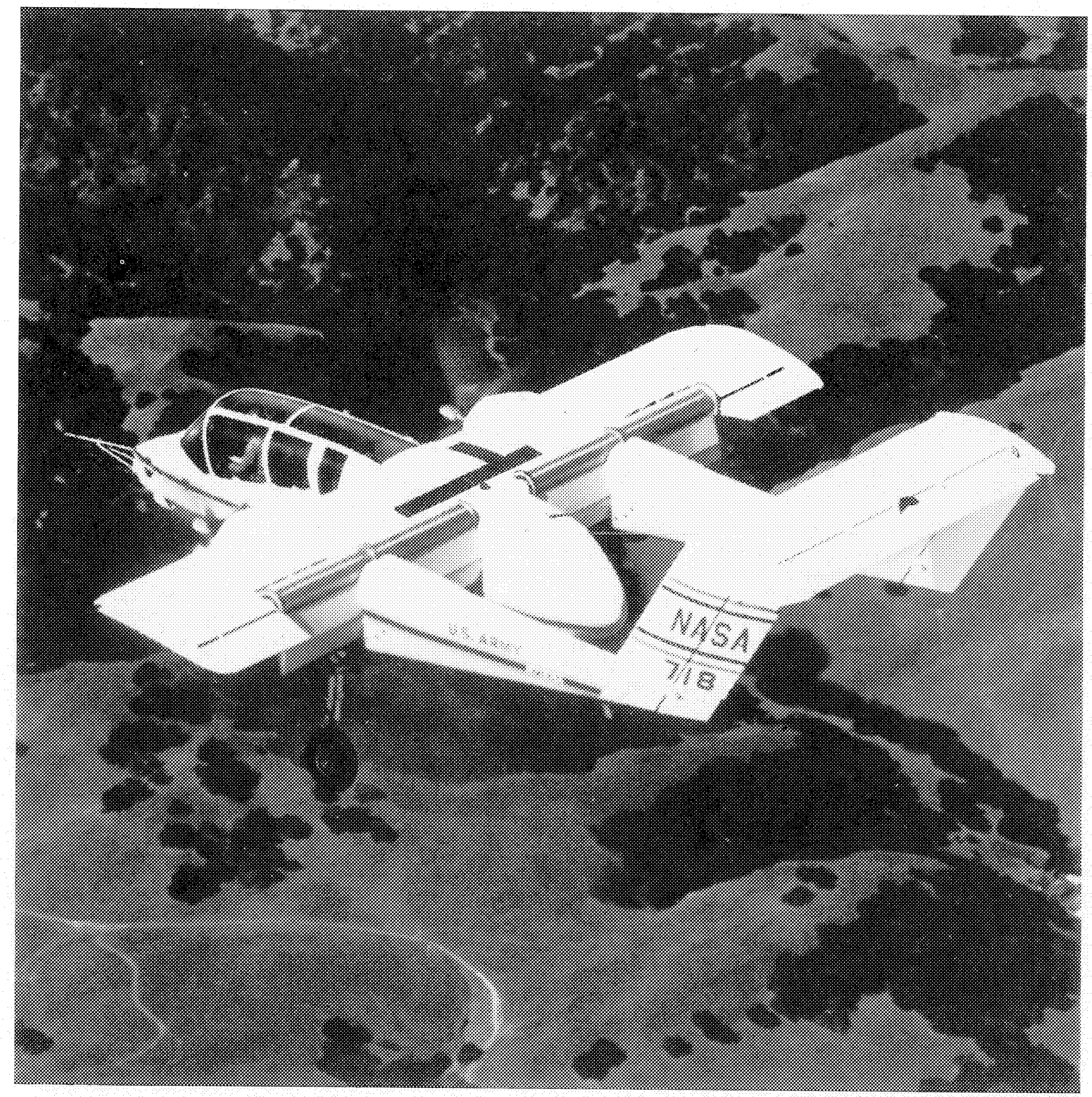

VINTEN MULTI-SPECTRAL PHOTO IMAGERY SYSTEM




49 ft. 9 in.
15 ft. 2 in.
EQUIPMENT BAY LOWER HATCH
TAIL GEAR
AUXILIARY GEAR (POGOS)
WING TIP SKID
50 ft. 6 in.
80 ft. 2 in.



8. YOV-10A STOL RESEARCH AIRCRAFT



DESCRIPTION:

The YOV-10A STOL Research Aircraft is a modified, twin-engine turboprop aircraft manufactured by Rockwell International, and designated NASA-718. Major modifications to the aircraft include a new high-lift concept which utilizes a rotating cylinder in the trailing edge flaps, and an improved propulsion system with interconnected propellers. The YOV-10A has a practical operating range of about 100 nautical miles at 130 knots indicated air speed, an operating ceiling of about 10,000 ft., and a useful payload of 940 lbs. It has been flown to indicated air speeds as low as 47 knots. This aircraft is equipped with an 80 channel digital data recording system.

The YOV-10A is used to research the aerodynamic characteristics of deflected slipstream vehicles and to evaluate the handling qualities and operating restrictions of powered-lift STOL aircraft. This program is jointly sponsored by the U.S. Army and NASA.

PERFORMANCE:

Takeoff weight	11,800 lbs, max.
Basic weight (less fuel and payload)	9,500 lbs
Fuel weight	1,360 lbs
Wing loading	48 lb/ft^2, max.
Takeoff distance	900 ft
Landing distance	900 ft

STATUS:

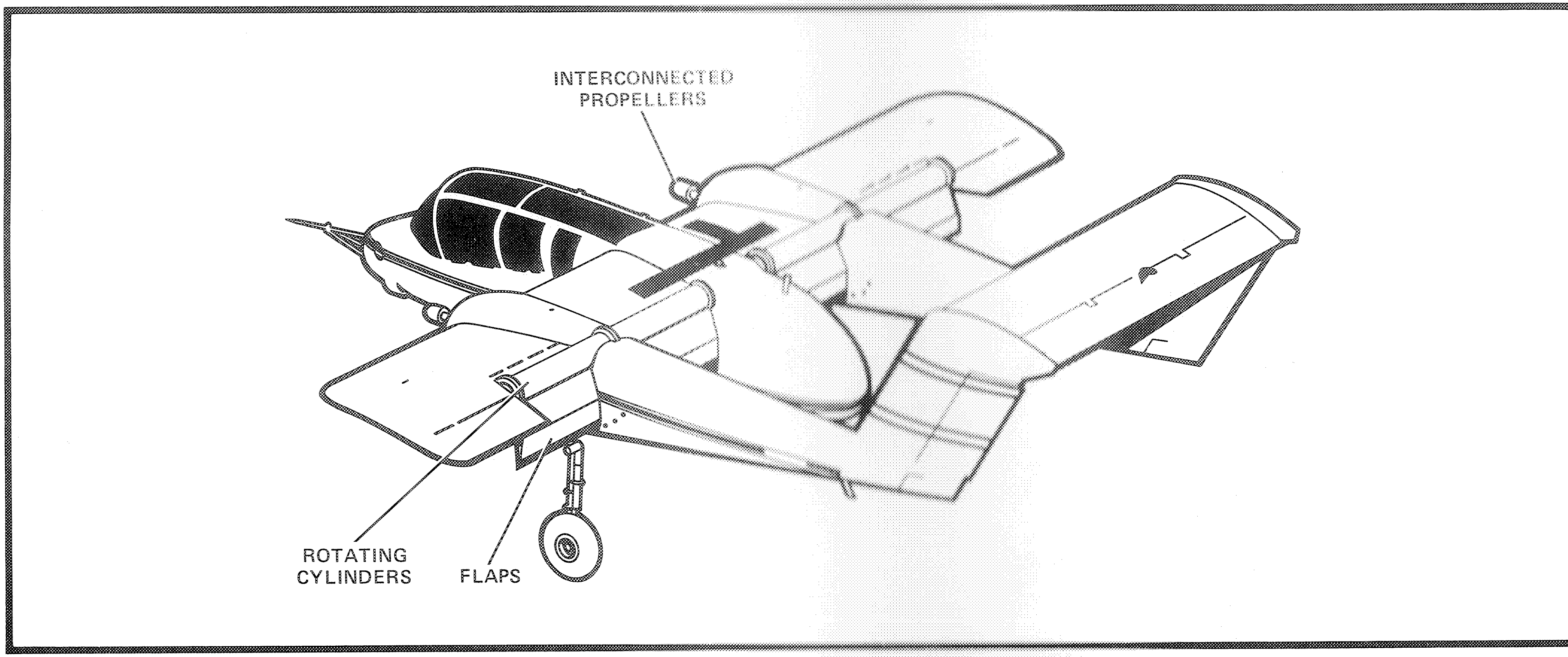
Operational since 1971

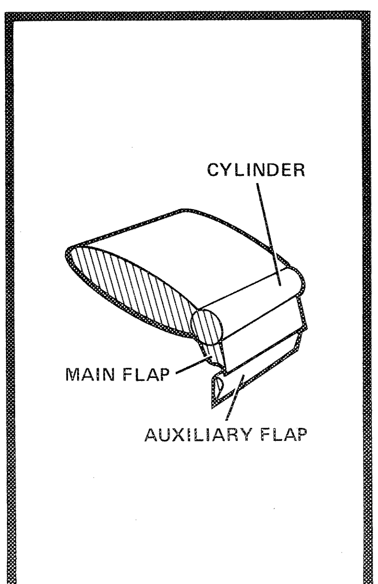
JURISDICTION:

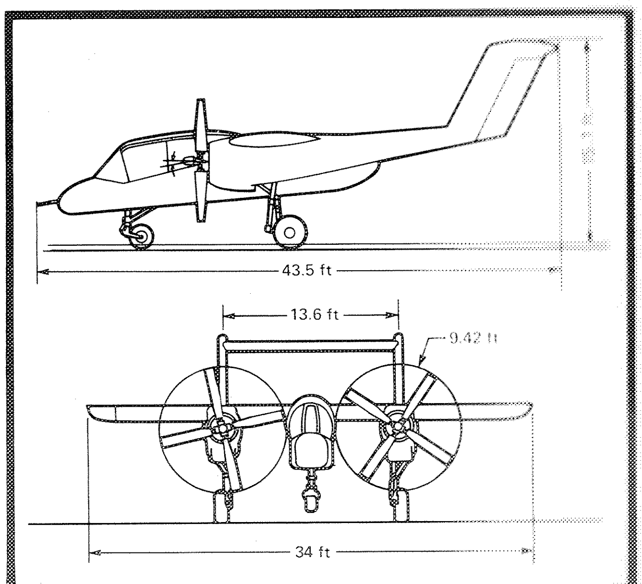
Flight Systems Research Division
Flight and Systems Research Branch
Maurice D. White

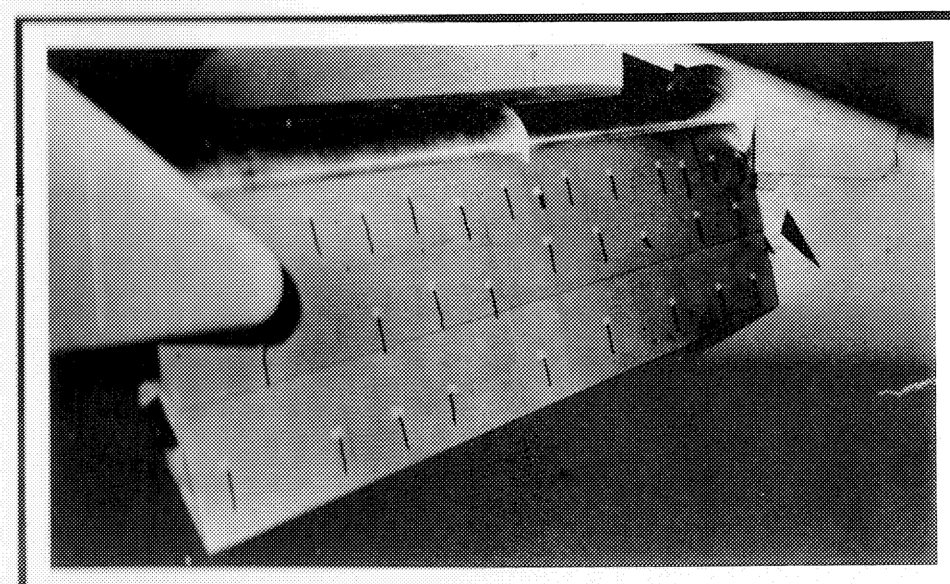
LOCATION:

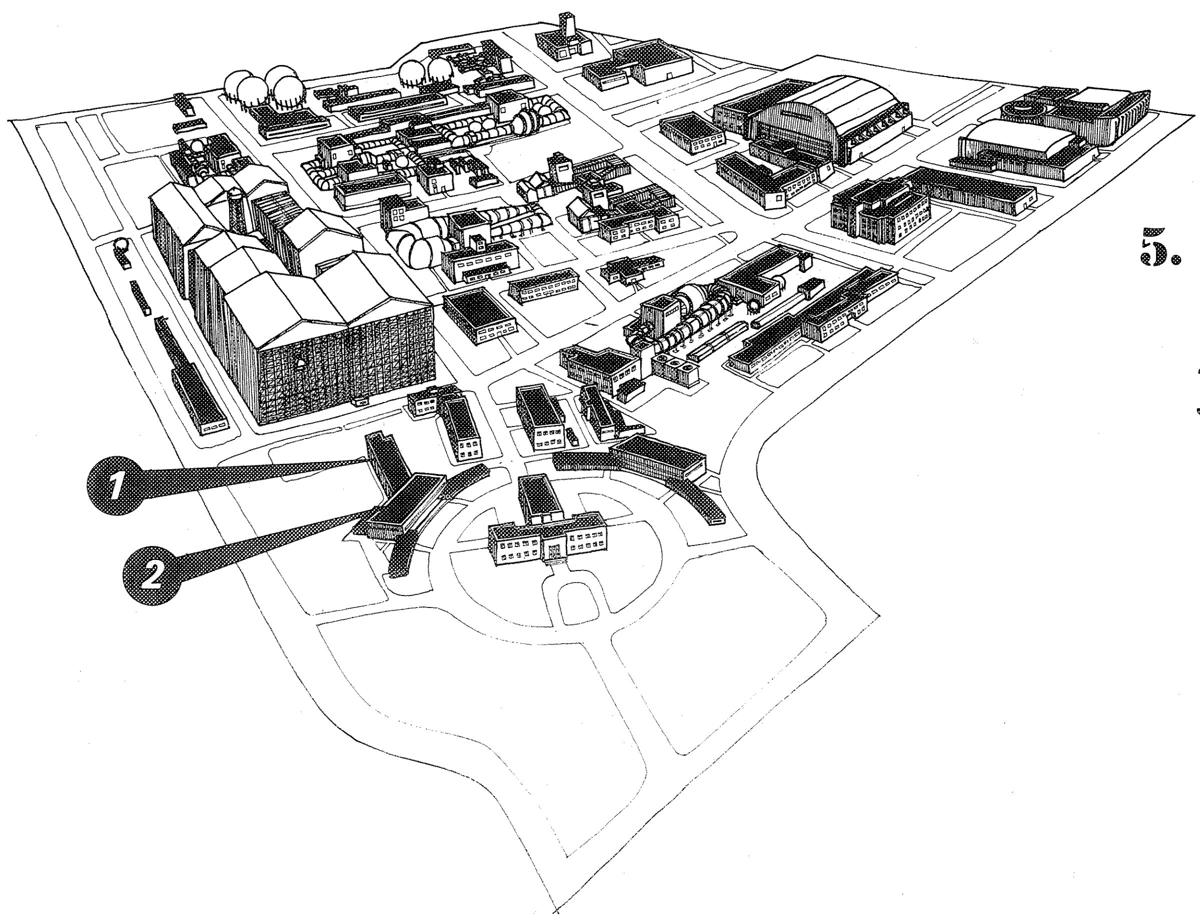
Building N-211


INTERCONNECTED
PROPELLERS
ROTATING
CYLINDERS
FLAPS


CYLINDER
MAIN FLAP
AUXILIARY FLAP


43.5 ft
13.6 ft
9.42 ft
34 ft

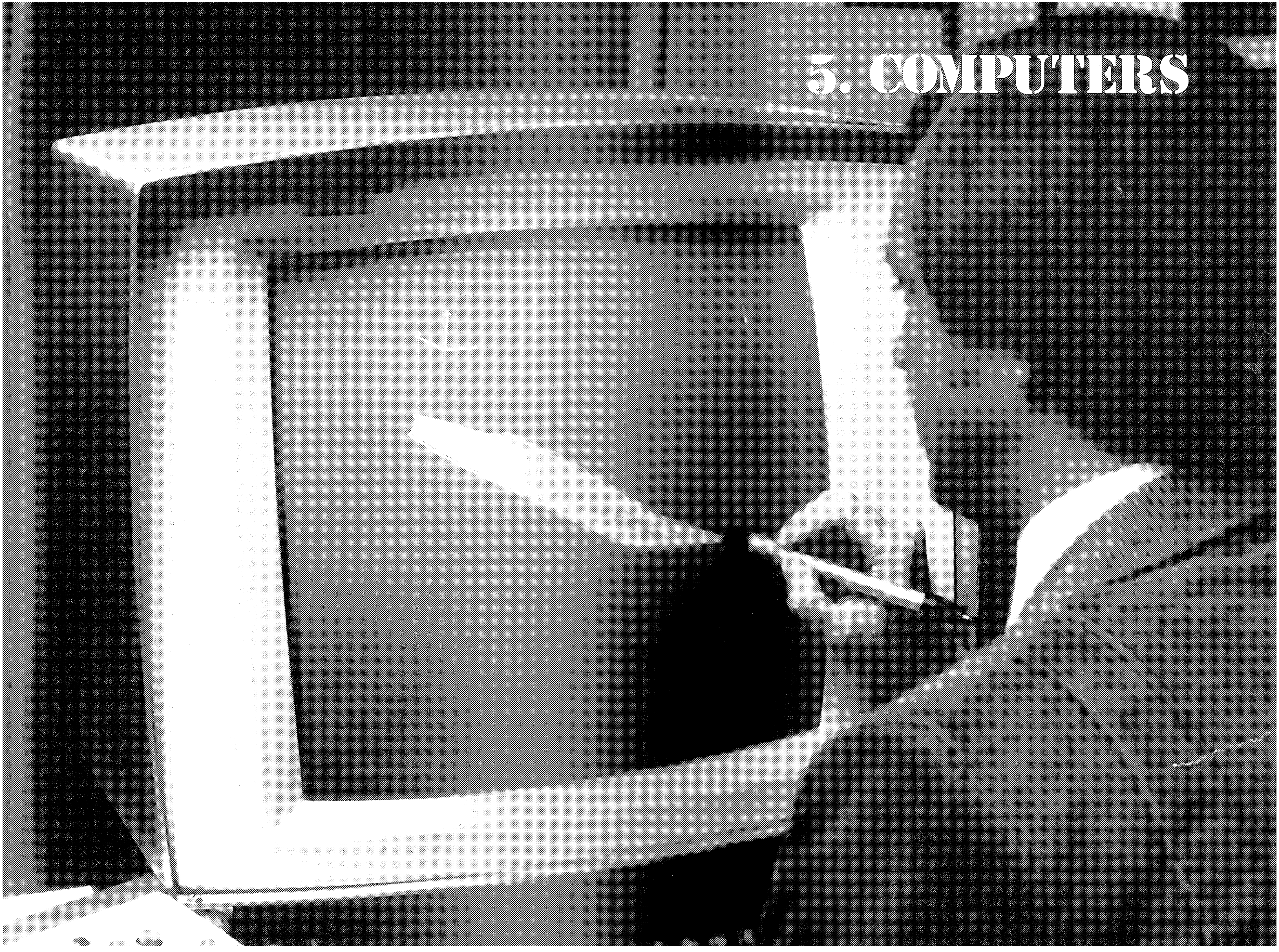




5. COMPUTERS

1. *ILLIAC IV*
2. *CENTRAL COMPUTER FACILITY*
3. *ADDITIONAL COMPUTATION FACILITIES, RESOURCE SHARING AND OUTSIDE SERVICES LOCATED THROUGHOUT THE CENTER.*

5. COMPUTERS



1. ILLIAC IV

DESCRIPTION:

The Illiac IV Computer System is housed at Ames in a specially built 30,000 square foot laboratory. It provides capabilities which will initially be applied to aerodynamic flow calculations, climate dynamics predictions, digital image processing, and arms limitations analyses sponsored by NASA and the Advanced Research Projects Agency (ARPA) - applications heretofore severely limited by the capacity of existing computer machinery. Access to Illiac IV will be provided by a nationwide high-speed data communications network, ARPA-NET, linking the computers of some 35 plus member-node installations, including such universities as Carnegie-Mellon, Case Western Reserve, Harvard, MIT, Stanford, UCLA, and USC, and other government agencies such as the National Bureau of Standards and the Department of Commerce.

The Illiac IV represents a new form of computer architecture, consisting of a parallel array organization employing a single control unit and 64 high-speed processing units. For problems in which a single list of instructions can effectively operate simultaneously on multiple sources of data, this organization provides an effective speed considerably greater than more conventional serial computers. In addition to the more than eight million bits of memory in the processing units, the system has, as secondary storage, a Parallel Disk File System which provides one billion bits of memory with a transfer rate of one billion bits per second, and an archival storage system, UNICON, with a trillion bit laser memory capacity.

Illiac IV can provide support in such areas as computational aerodynamics, global climate dynamics, distant seismic event simulation, and optimization problems arising in logistics or economics.

JURISDICTION:

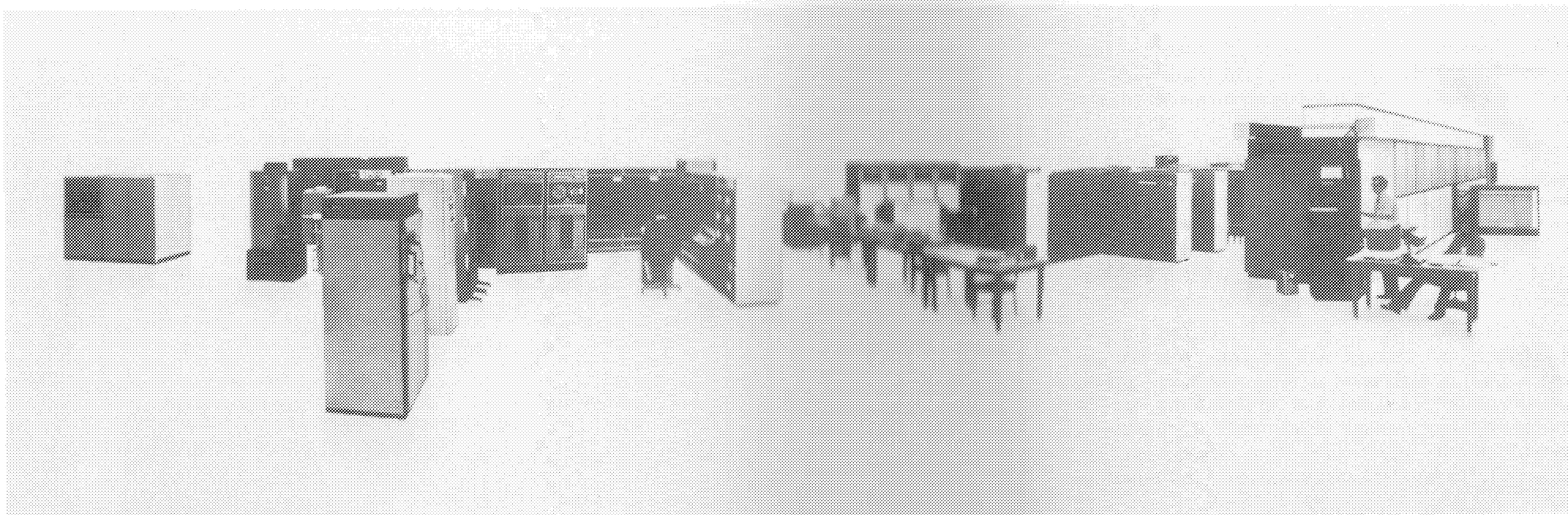
Institute for Advanced Computation
Dr. Melvin W. Pirtle

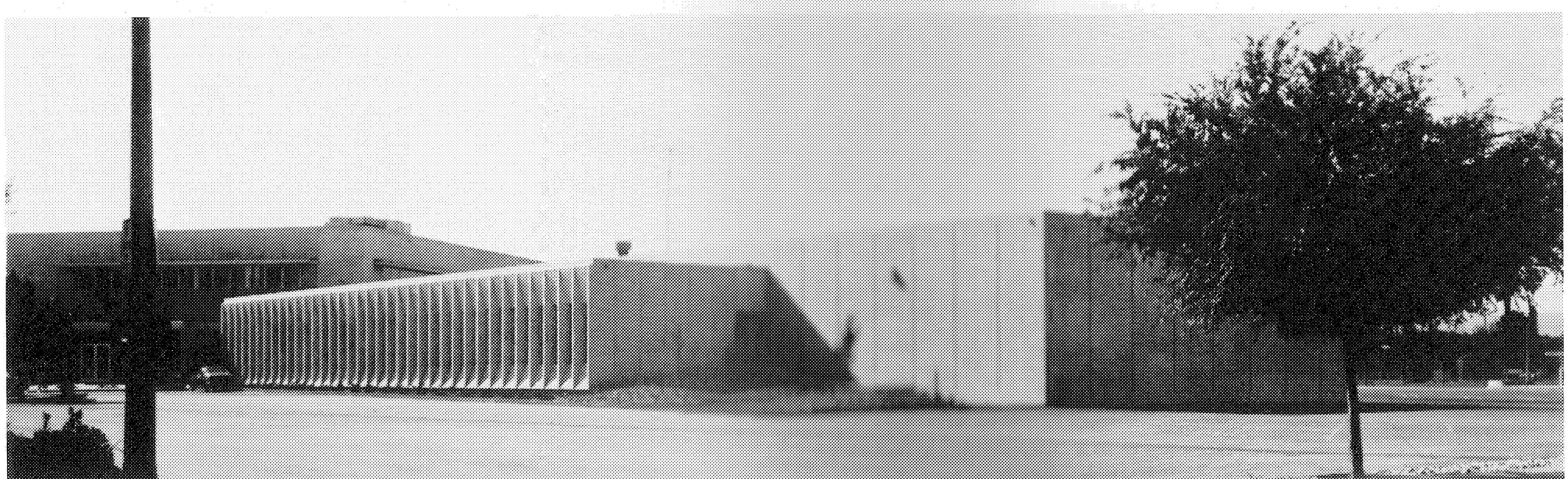
STATUS:

Operational since 1973

LOCATION:

Building N-233





2. CENTRAL COMPUTER FACILITY

DESCRIPTION:

The Central Computer Facility comprises almost 10,000 square feet of space dedicated to the IBM Duplex 360/67, IBM 7040-7094, Honeywell 800/200, and interactive graphics systems.

The IBM Duplex 360/67 is designed to operate in both the timesharing (TSS/360) and batch (OS/360) environment. This system includes remote access capability along with standard peripheral devices as well as interactive capability for many users operating simultaneously at various terminals. The IBM 7040-7094 computers work as a direct-coupled (DCS) system. The Honeywell 800/200 computers operate as one system.

Computation services provided include the use of software services contracts and in-house staff for comprehensive programming support in such areas as wind tunnel data processing, satellite data processing and analysis, life sciences experimental data processing, aerodynamics computations, plotting and graphics applications, data management, systems support for small dedicated computers, and numerical control.

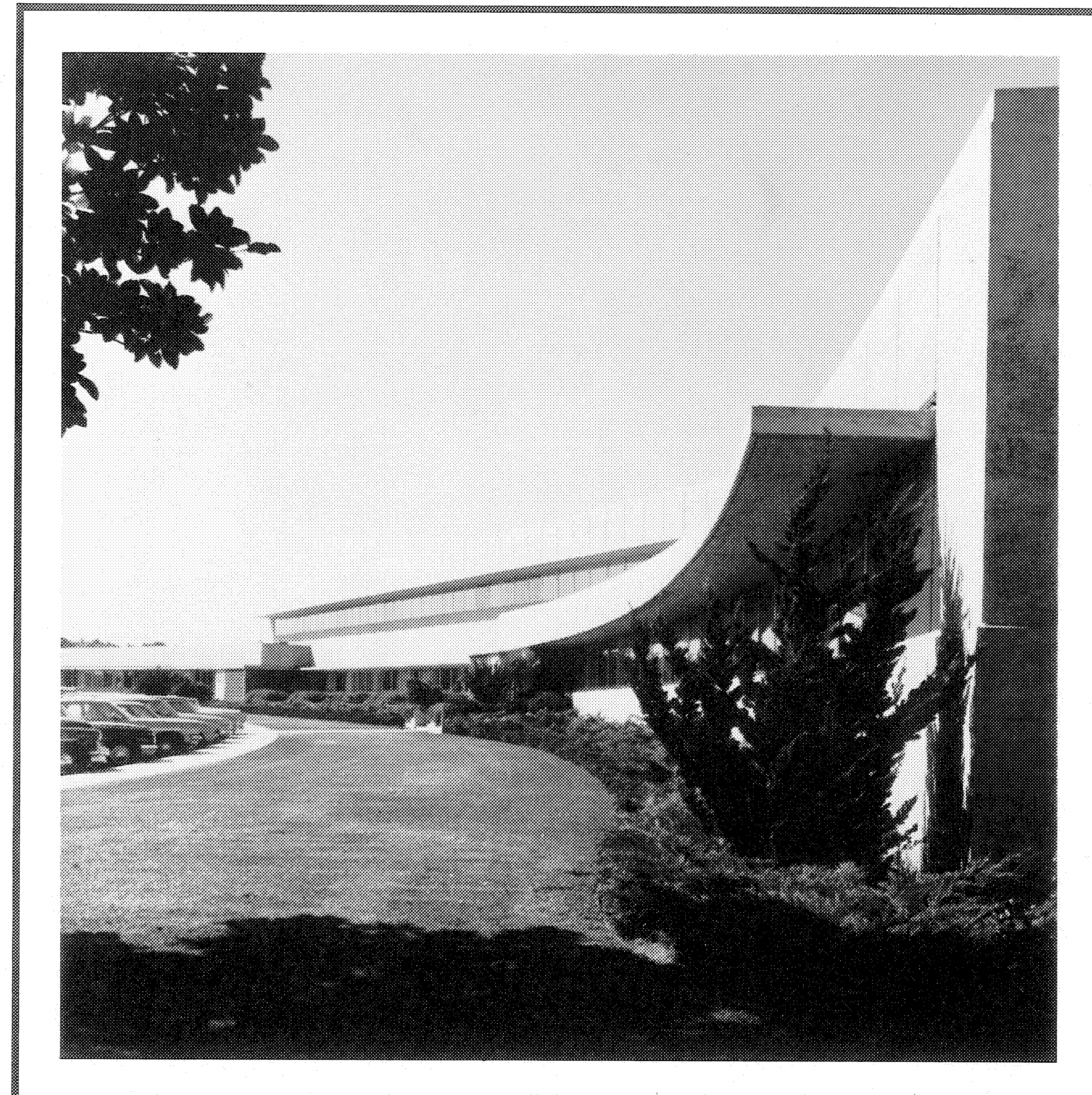
There are a number of programming languages available. Most commonly used and widely accepted is the FORTRAN programming language. COBOL is used primarily in accounting areas, RPG for required report generation, and PL/1, a generalized language, is useful in both scientific and accounting problems.

JURISDICTION:

Computation Division
Thomas R. Dines

LOCATION:

Building N-233



System	Usage	Memory	Applications	Peripherals	I/O Devices	Software
IBM 360/67	Interactive terminal-oriented system providing both time-shared and batch capabilities. Network-data base usage.	Two million bytes of core storage with virtual memory to run large programs without overlays.	[illegible]	9-track tape drives (4), 7-track tape drives (6), disk storage units (4), voice-grade telephone (full duplex).	Local and remote card input, local and remote printers, 2741-type terminals (59), teletypewriters (38), 2780 RJE's (6).	OS/TSS (operating systems), Fortran IV, PL/1, Assembler, WATFOR, GPSS, CSMP.
IBM 7040-7094	Batch oriented system providing general digital processing service with direct-coupled linkage between 7040 and 7094 (DCS).	IBM 7094 has 32,768 words of core memory but without I/O channels. IBM 7040 has 32,768 words of core memory and receives and transmits data through four I/O channels.	[illegible]	7-track tape drives (8), 1301 disk storage units (2).	Card reader/punch (800 CPM/250 CPM), printers (2) (600 lpm).	IBSYS (operating system), Fortran IV, Cobol, RPG.
H-800	Batch oriented system providing utility services.	H-800 has 28K 48-bit words of memory.	[illegible]	3/4 inch tape drives (8) paper/tape reader punch (Beckman), (Control Data) (2) paper tape punch (Burroughs (2) plotter readers (Burroughs (2) Modified IBM card reader punch teletypewriters (3)	H-200	Admiral (Thor Automath-800), Abacus, Algebraic Compiler 1, Fortran IV, Cobol, Argus assembly language.
H-200	Utility services only.	Two-address, alphanumeric system with internal storage of 16,384 character positions.	[illegible]	1/2 inch tape drives (2) 3/4 inch tape drives (2)	227 Card Reader (800 CPM) 209 Paper Tape Reader (600 CPM) 227 Card Punch (250 CPM) 210 Paper Tape Punch (120 CPM) 206 Printer (500 CPM) 212-1 On-line Adapter	Easy coder — Utilities: • Tape handling option routines • System for coordination of peripherals • Control of on-line peripheral devices • Printer test • Program assembly/production • Program production
IBM 1800	Interface with IBM 360/67 for graphics applications.	Full 32,768 16-bit words.	[illegible]	[illegible]	1443 Printer 1442 Card Reader Punch 1816 Printer Keyboard Adapter	

3. ADDITIONAL COMPUTATION FACILITIES, RESOURCE SHARING AND OUTSIDE SERVICES

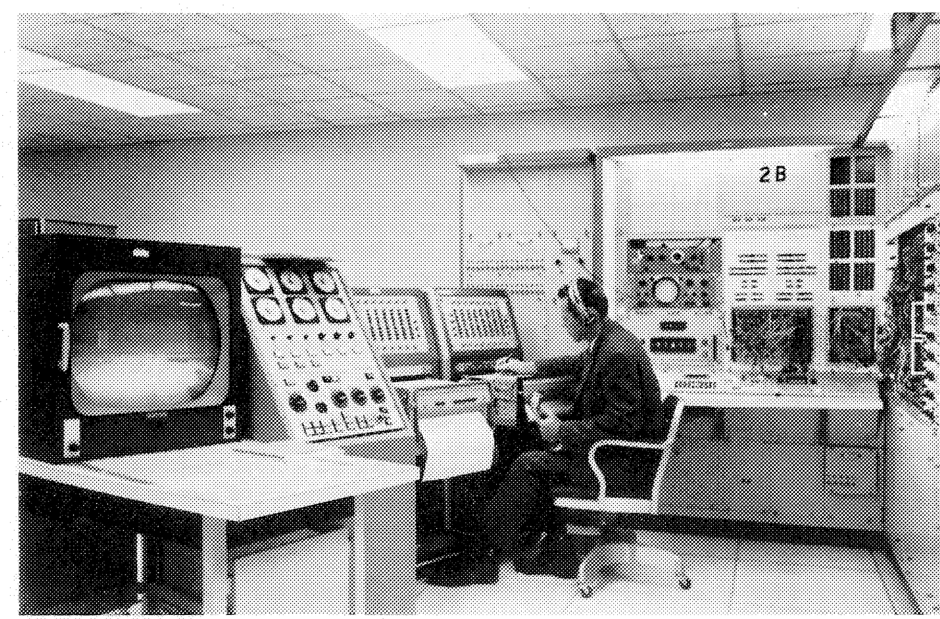
DESCRIPTION:

In addition to the Central Computer Facility and the Illiac IV Computer (ARPA) Network, other services available include a timesharing CDC 6600/7600 batch service with the Lawrence Berkeley Laboratory, including a courier service for print-outs of long duration (more than 30 minutes or around 100 pages).

Additionally, other support systems have been installed in research facilities throughout the Center; an IBM 1800 in the Army Air Mobility Research and Development Laboratory, Building N-215; an IBM 1800 and SEL 840 MP in the Life Sciences Research Laboratory, Building N-239; an SEL 810 in the Atmosphere and Astrophysics Research Facility, Building N-245; an SEL 840 MP in the Large-Scale Aerodynamics Wind Tunnel Facility, Building N-221; two Sigma 7's in the Manned System Simulation Facilities, Building N-243; one PPS 1020 in the Flight Simulation Laboratory, Building N-210; one PPS 1020 located in the Unitary Plan Wind Tunnel Facility, Building N-227. Mini-Computers are used in instrumentation and communication systems including a set of eight for use as controllers in the Center's major wind tunnel facilities (these systems can be interfaced to the Central Computer Facility over telephone lines).

To augment its computer facilities, the Center contracts with several commercial time-sharing services including Tymshare, Inc. (FORTRAN, BASIC, ADAPT); National CSS, Inc. (FORTRAN, PL/1, Stru-Pak); PCS, Inc. (Administrative Terminal System); General Electric, Inc. (Numerical Control); University of California, Davis (Illiac IV simulator service); University of California, San Diego (Illiac IV simulator service).

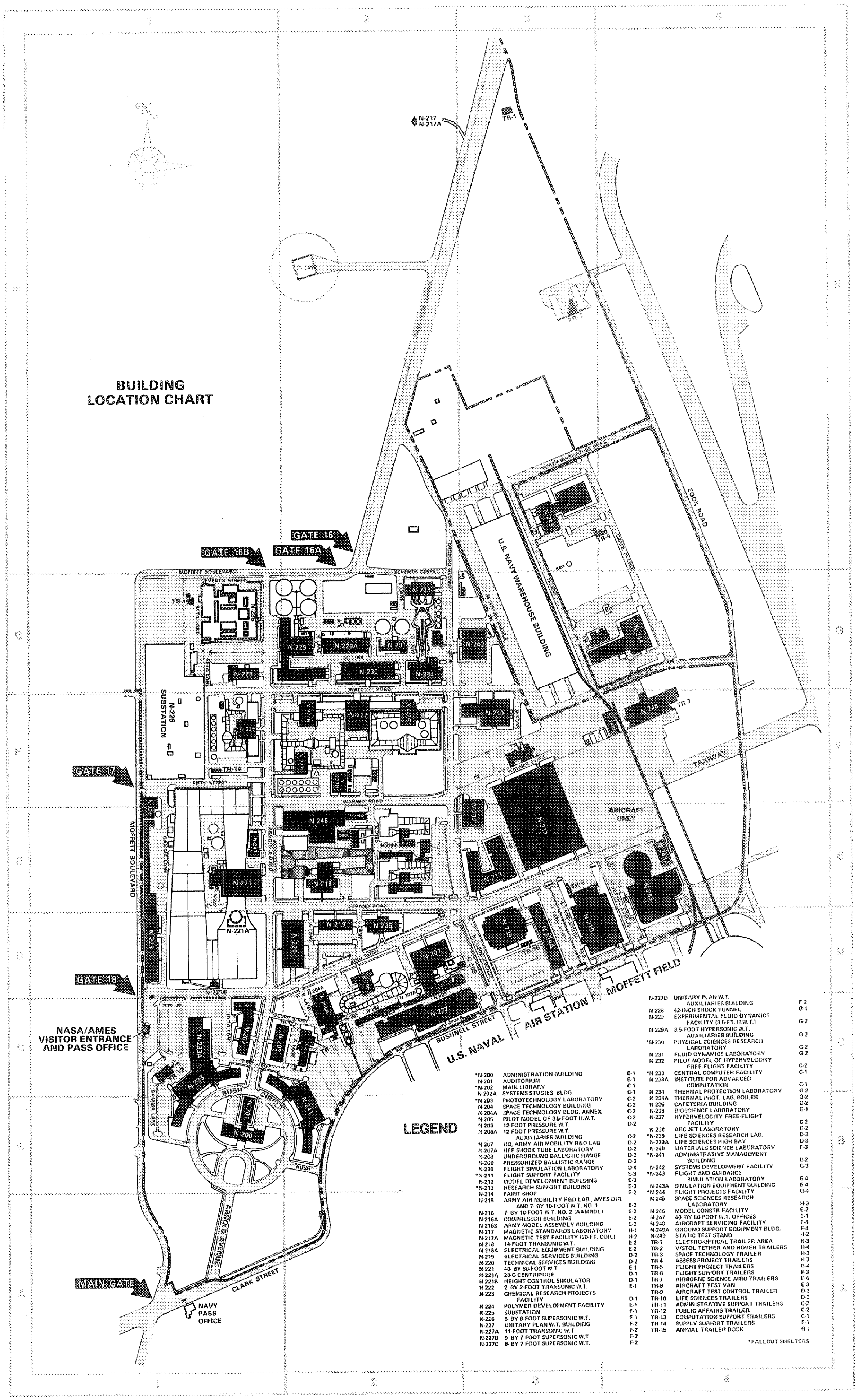
Close contact and communication is maintained with other NASA computation facilities and agencies in order to exchange ideas and techniques whenever possible. Ames is a member of the NASA Intercenter Committee on ADP and of the Task Group on Education and Training as well. Programming Data and techniques in a wide variety of applications, Computer User Manuals, Procedures, User Newsletters and Bulletins are also exchanged. A Computer Science Information Center (CSCI) in Building N-233 maintains all standards information along with User Group Exchange Information.


2B

SIGNIFICANT ACCOMPLISHMENTS

- Comprehensive studies of future short takeoff and landing (STOL) transportation systems
- Research leading to development of fire resistant plastics
- Development and management of the Pioneer 10 and 11 spacecraft, first to explore the outer solar system
- Discovery of life-related molecules - amino acids and pyrimidines - believed to be of extraterrestrial origin in meteorites
- Flight research with the first jet-STOL experimental aircraft
- Discovery of concept of bluntness for atmospheric entry
- Use of advanced flight simulators to provide certification information for supersonic and V/STOL transport aircraft
- Development of a new model of the lunar interior from lunar magnetic field measurements
- Medical applications of the life sciences technology generated by the space program
- Specification of the first quiet Jet-STOL transport research aircraft
- Development of advanced computing techniques for basic fluid flows and for flows over airfoils, wings and tails
- Significant scientific results from Project Pioneer, including new discoveries about the solar atmosphere and the Earth's "magnetic tail."
- Application of atmosphere entry aerodynamics to the study of tektites
- Development of experiments to determine whether life exists on Mars
- Development of Tilt-Rotor concepts for V/STOL aircraft
- Development of computer-generated visual displays to aid in understanding pilot performance
- Development of navigation and guidance concepts and techniques for the Apollo mission
- Synthesis of various life "building blocks" that demonstrate part of the chemical evolution of life
- Exploratory projects with state and local agencies in disaster assessment and definition of pollution problems

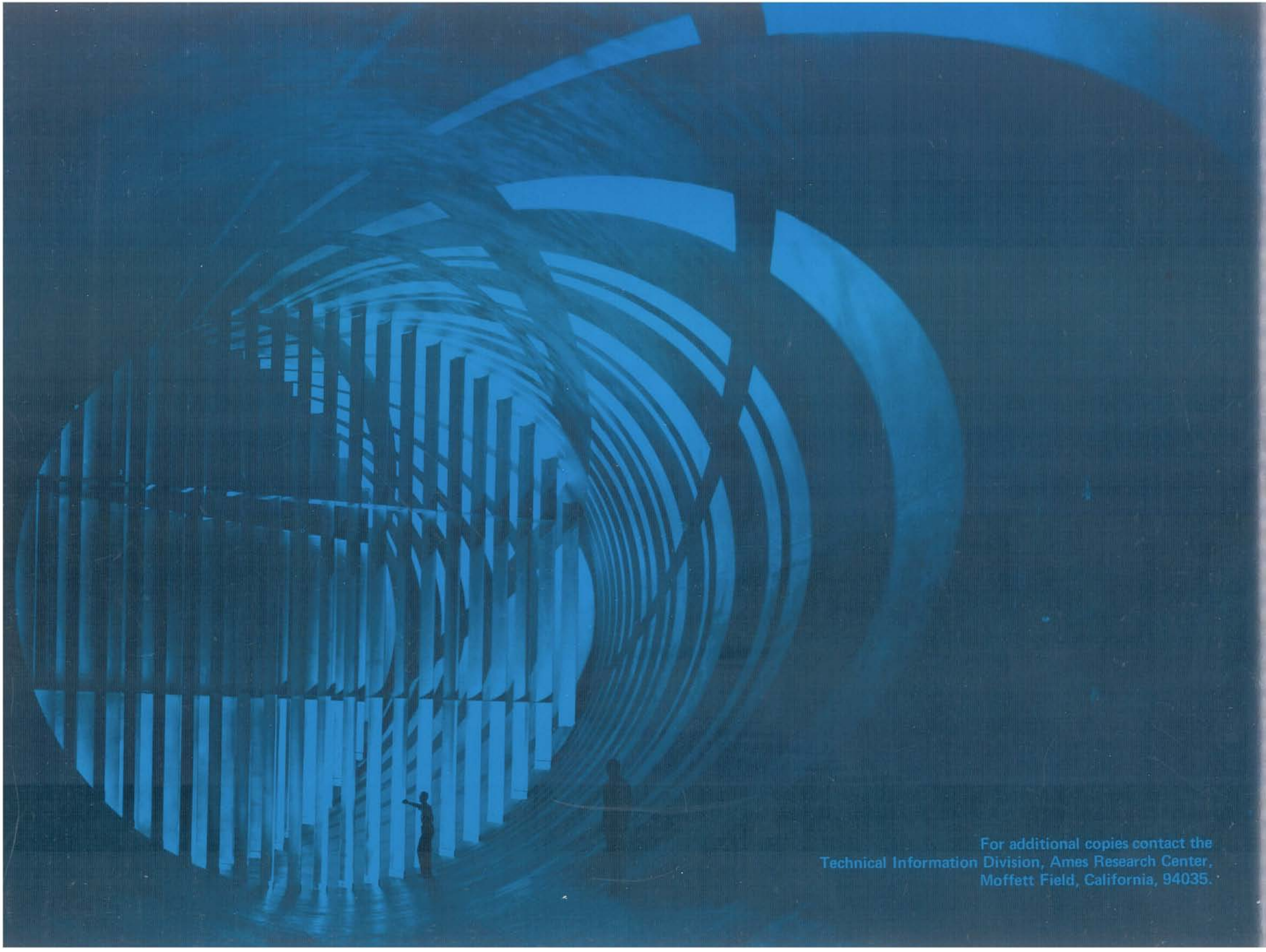
BUILDING LOCATION CHART



LEGEND

*N-200	ADMINISTRATION BUILDING	B-1
N-201	AUDITORIUM	B-1
*N-202	MAIN LIBRARY	C-1
N-202A	SYSTEMS STUDIES BLDG.	C-1
*N-203	PHOTOTECHNOLOGY LABORATORY	C-2
N-204	SPACE TECHNOLOGY BUILDING	C-2
N-204A	SPACE TECHNOLOGY BLDG. ANNEX	C-2
N-205	PILOT MODEL OF 3.5-FOOT H.W.T.	C-2
N-206	12-FOOT PRESSURE W.T.	D-2
N-206A	12-FOOT PRESSURE W.T. AUXILIARIES BUILDING	C-2
N-207	HQ, ARMY AIR MOBILITY R&D LAB	D-2
N-207A	HFF SHOCK TUBE LABORATORY	D-2
N-208	UNDERGROUND BALLISTIC RANGE	D-2
N-209	PRESSURIZED BALLISTIC RANGE	D-3
N-210	FLIGHT SIMULATION LABORATORY	D-4
*N-211	FLIGHT SUPPORT FACILITY	E-3
N-212	MODEL DEVELOPMENT BUILDING	E-3
*N-213	RESEARCH SUPPORT BUILDING	E-3
N-214	PAINT SHOP	E-2
N-215	ARMY AIR MOBILITY R&D LAB., AMES DIR. AND 7- BY 10-FOOT W.T. NO. 1	E-2
N-216	7- BY 10-FOOT W.T. NO. 2 (AAMRDL)	E-2
N-216A	COMPRESSOR BUILDING	E-2
N-216B	ARMY MODEL ASSEMBLY BUILDING	E-2
N-217	MAGNETIC STANDARDS LABORATORY	H-1
N-217A	MAGNETIC TEST FACILITY (20-FT. COIL)	H-2
N-218	14-FOOT TRANSONIC W.T.	E-2
N-218A	ELECTRICAL EQUIPMENT BUILDING	E-2
N-219	ELECTRICAL SERVICES BUILDING	D-2
N-220	TECHNICAL SERVICES BUILDING	D-2
N-221	40- BY 80-FOOT W.T.	E-1
N-221A	20-G CENTRIFUGE	D-1
N-221B	HEIGHT CONTROL SIMULATOR	D-1
N-222	2- BY 2-FOOT TRANSONIC W.T.	E-1
N-223	CHEMICAL RESEARCH PROJECTS FACILITY	D-1
N-224	POLYMER DEVELOPMENT FACILITY	E-1
N-225	SUBSTATION	F-1
N-226	6- BY 6-FOOT SUPERSONIC W.T.	F-1
N-227	UNITARY PLAN W.T. BUILDING	F-2
N-227A	11-FOOT TRANSONIC W.T.	F-2
N-227B	9- BY 7-FOOT SUPERSONIC W.T.	F-2
N-227C	8- BY 7-FOOT SUPERSONIC W.T.	F-2
N-227D	UNITARY PLAN W.T. AUXILIARIES BUILDING	F-2
N-228	42-INCH SHOCK TUNNEL	G-1
N-229	EXPERIMENTAL FLUID DYNAMICS FACILITY (3.5-FT. H.W.T.)	G-2
N-229A	3.5-FOOT HYPERSONIC W.T. AUXILIARIES BUILDING	G-2
*N-230	PHYSICAL SCIENCES RESEARCH LABORATORY	G-2
N-231	FLUID DYNAMICS LABORATORY	G-2
N-232	PILOT MODEL OF HYPERVELOCITY FREE-FLIGHT FACILITY	C-2
*N-233	CENTRAL COMPUTER FACILITY	C-1
N-233A	INSTITUTE FOR ADVANCED COMPUTATION	C-1
N-234	THERMAL PROTECTION LABORATORY	G-2
N-234A	THERMAL PROT. LAB. BOILER	G-2
N-235	CAFETERIA BUILDING	D-2
N-236	BIOSCIENCE LABORATORY	G-1
N-237	HYPERVELOCITY FREE-FLIGHT FACILITY	C-2
N-238	ARC JET LABORATORY	G-2
*N-239	LIFE SCIENCES RESEARCH LAB.	D-3
N-239A	LIFE SCIENCES HIGH BAY	D-3
N-240	MATERIALS SCIENCE LABORATORY	F-3
*N-241	ADMINISTRATIVE MANAGEMENT BUILDING	B-2
N-242	SYSTEMS DEVELOPMENT FACILITY	G-3
*N-243	FLIGHT AND GUIDANCE SIMULATION LABORATORY	E-4
N-243A	SIMULATION EQUIPMENT BUILDING	E-4
*N-244	FLIGHT PROJECTS FACILITY	G-4
N-245	SPACE SCIENCES RESEARCH LABORATORY	H-3
N-246	MODEL CONSTR FACILITY	E-2
N-247	40- BY 80-FOOT W.T. OFFICES	E-1
N-248	AIRCRAFT SERVICING FACILITY	F-4
N-248A	GROUND SUPPORT EQUIPMENT BLDG.	F-4
N-249	STATIC TEST STAND	H-2
TR-1	ELECTRO-OPTICAL TRAILER AREA	H-3
TR-2	V/STOL TETHER AND HOVER TRAILERS	H-4
TR-3	SPACE TECHNOLOGY TRAILER	H-3
TR-4	ASSESS PROJECT TRAILERS	H-3
TR-5	FLIGHT PROJECT TRAILERS	G-4
TR-6	FLIGHT SUPPORT TRAILERS	F-3
TR-7	AIRBORNE SCIENCE AIRO TRAILERS	F-4
TR-8	AIRCRAFT TEST VAN	E-3
TR-9	AIRCRAFT TEST CONTROL TRAILER	D-3
TR-10	LIFE SCIENCES TRAILERS	D-3
TR-11	ADMINISTRATIVE SUPPORT TRAILERS	C-2
TR-12	PUBLIC AFFAIRS TRAILER	C-2
TR-13	COMPUTATION SUPPORT TRAILERS	C-1
TR-14	SUPPLY SUPPORT TRAILERS	F-1
TR-15	ANIMAL TRAILER DOCK	G-1

*FALLOUT SHELTERS


For additional copies contact the
Technical Information Division, Ames Research Center,
Moffett Field, California, 94035.

Excerpts from NASA Ames Research Center, Ames Research Facilities Handbook (1982)

MARK J. WON (45865)

AHB 8801-1

RESEARCH FACILITIES HANDBOOK

NASA

National Aeronautics and Space Administration

Ames Research Center
Moffett Field, California 94035

June 1982

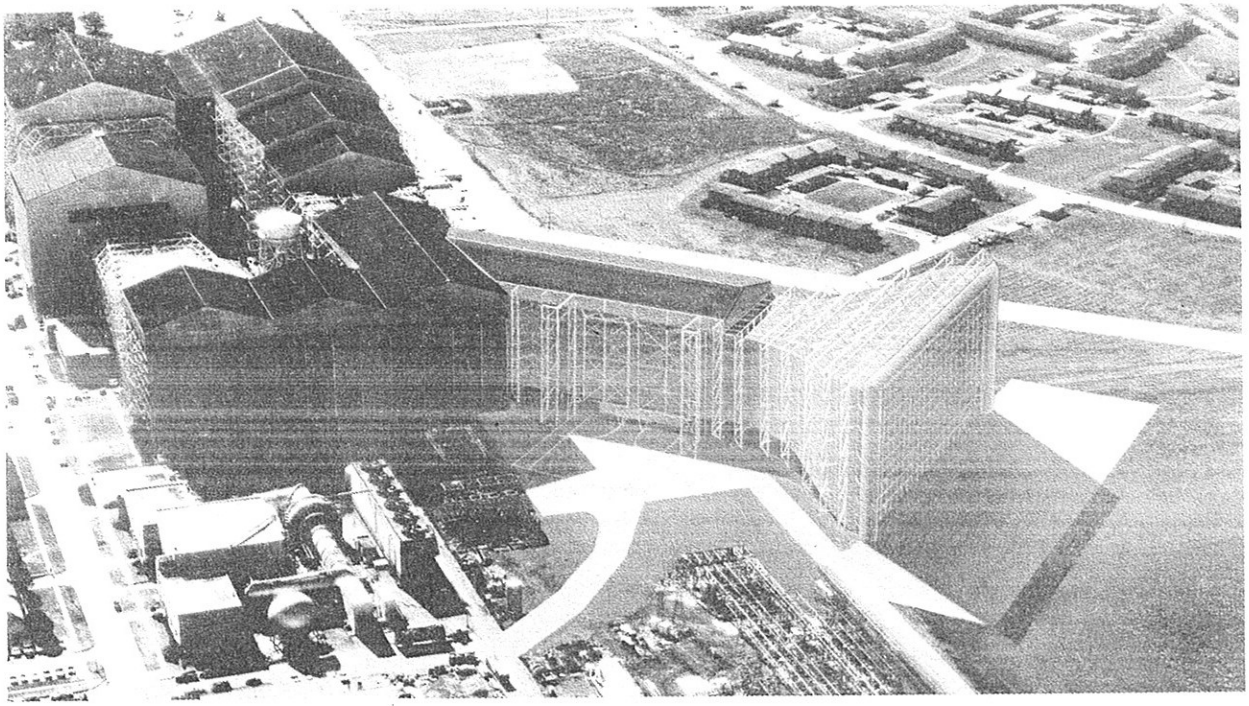
PREFACE

AHB 8801-1 – RESEARCH FACILITIES HANDBOOK. Ames Research Center, a field organization of the National Aeronautics and Space Administration, operates two research establishments: the Ames installation located at Moffett Field, California, and the Dryden installation located at Edwards, California. This handbook describes the most important of the highly specialized Ames-Moffett Field facilities, which consist of wind tunnels; high enthalpy and hypersonic wind tunnels, shock tubes, and ballistic ranges; flight simulation facilities; research aircraft; and computers.

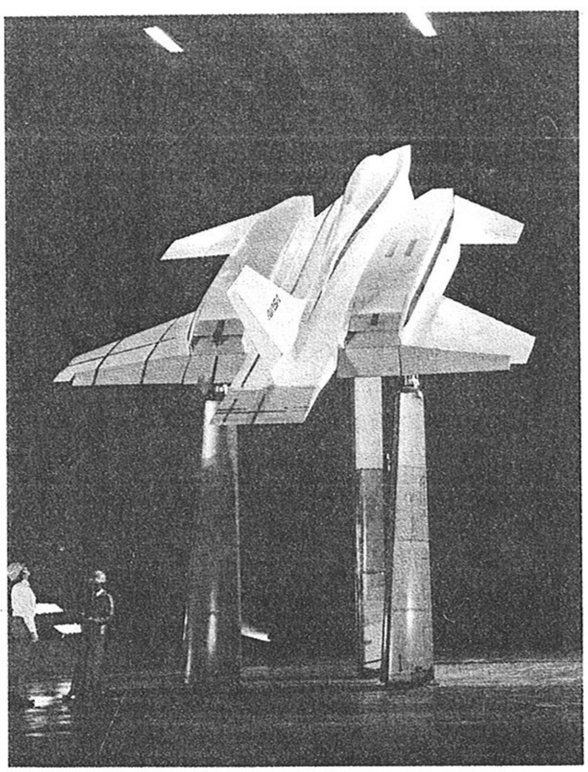
This handbook may be revised from time to time by page changes, additions, or complete new editions. Notice that a transmittal code is set at the lower binder margin of each page. All pages of the most recent complete edition are coded RFH-1 (for "Research Facilities Handbook – Transmittal No. 1"). Revised pages will be coded RFH-2, RFH-3, and so on, and a check list of pages in force by transmittal codes will be included in each transmittal that transmits other than a complete edition.

Comments and suggestions about this handbook and requests for extra copies should be submitted to RFA:213-1:6331/Chief, Facilities Planning Office.

1. 40- BY 80-FOOT/80- BY 120-FOOT SUBSONIC WIND TUNNEL

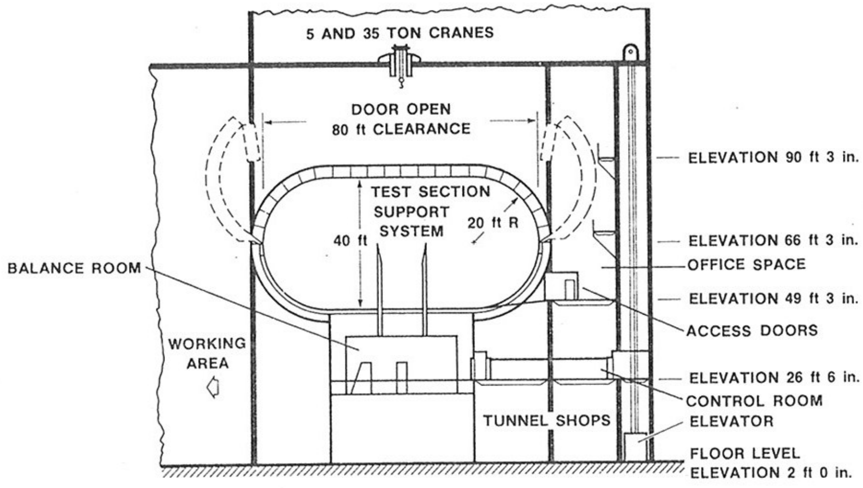


1. 40- BY 80-FOOT/80- BY 120-FOOT SUBSONIC WIND TUNNEL



The 40- by 80-Foot Wind Tunnel is presently undergoing modification. The modification includes repowering and a new 80- by 120-ft test section leg 80-ft high, 120-ft wide, and 190-ft long. Repowering of the facility will provide a test section velocity of 300 knots in the 40- by 80-ft test section. Both test sections will be powered by the same drive system. In the 80- by 120-ft test section configuration, the wind tunnel will be of the nonreturn type. Air will be drawn in from the atmosphere through a 5:1 contraction entrance cone, it will pass through the test section into the main drive section, and then it will be exhausted to the atmosphere through louvers at the south end of the existing wind tunnel. The maximum speed in this leg will be about 100 knots. The new main drive system will consist of six 18,000-hp continuous rating, synchronous motors, each driving a 15-blade variable pitch fan.

Power to operate helicopter rotors or powered lift V/STOL systems can be obtained from either aircraft engines or electric motors. JP-5 fuel can be supplied for turbojet/turbofan engines in each test section. A variety of electric motors are available for model propulsion systems (maximum electric power available for these is 3000 hp). A 3000-psi air supply system is available at the 40- by 80-ft test section.



PERFORMANCE:

40- by 80-Foot Tunnel

Speed, knots	0 to 300
Stagnation pressure, atm	1.0
Reynolds number, per ft	0 to 3×10^6
Temperature, °R	0 to 600

80- by 120-Foot Leg

Speed, knots	0 to 100
Stagnation pressure, atm	1.0
Reynolds number, per ft	0 to 1×10^6
Temperature, °R	0 to 600

DIMENSIONS:

	40- by 80-Foot	*80- by 120-Foot*
Height, ft	40	80
Width, ft	80	120
Length	80	190
Access	top doors	side doors

STATUS:

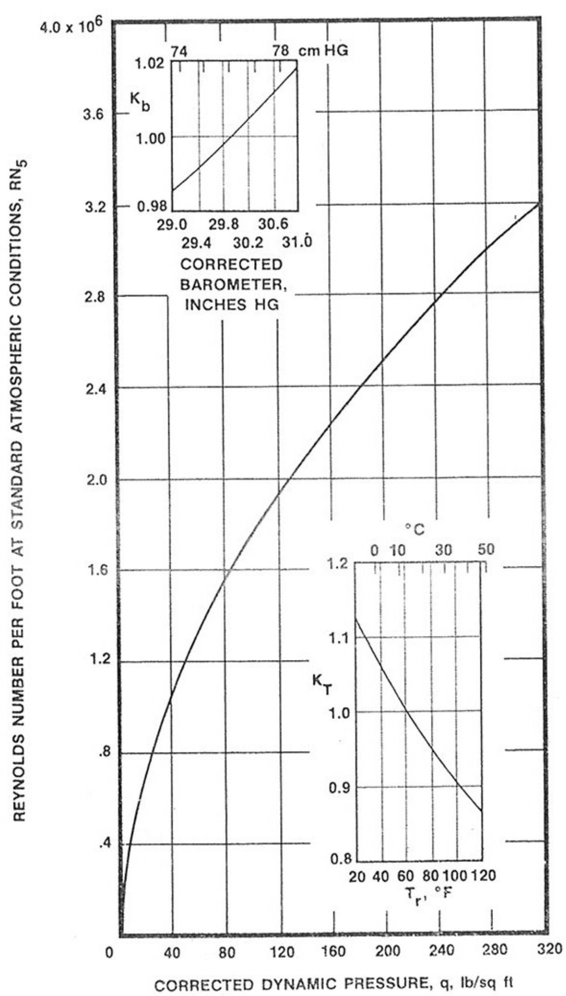
Operational in mid 1982

JURISDICTION:

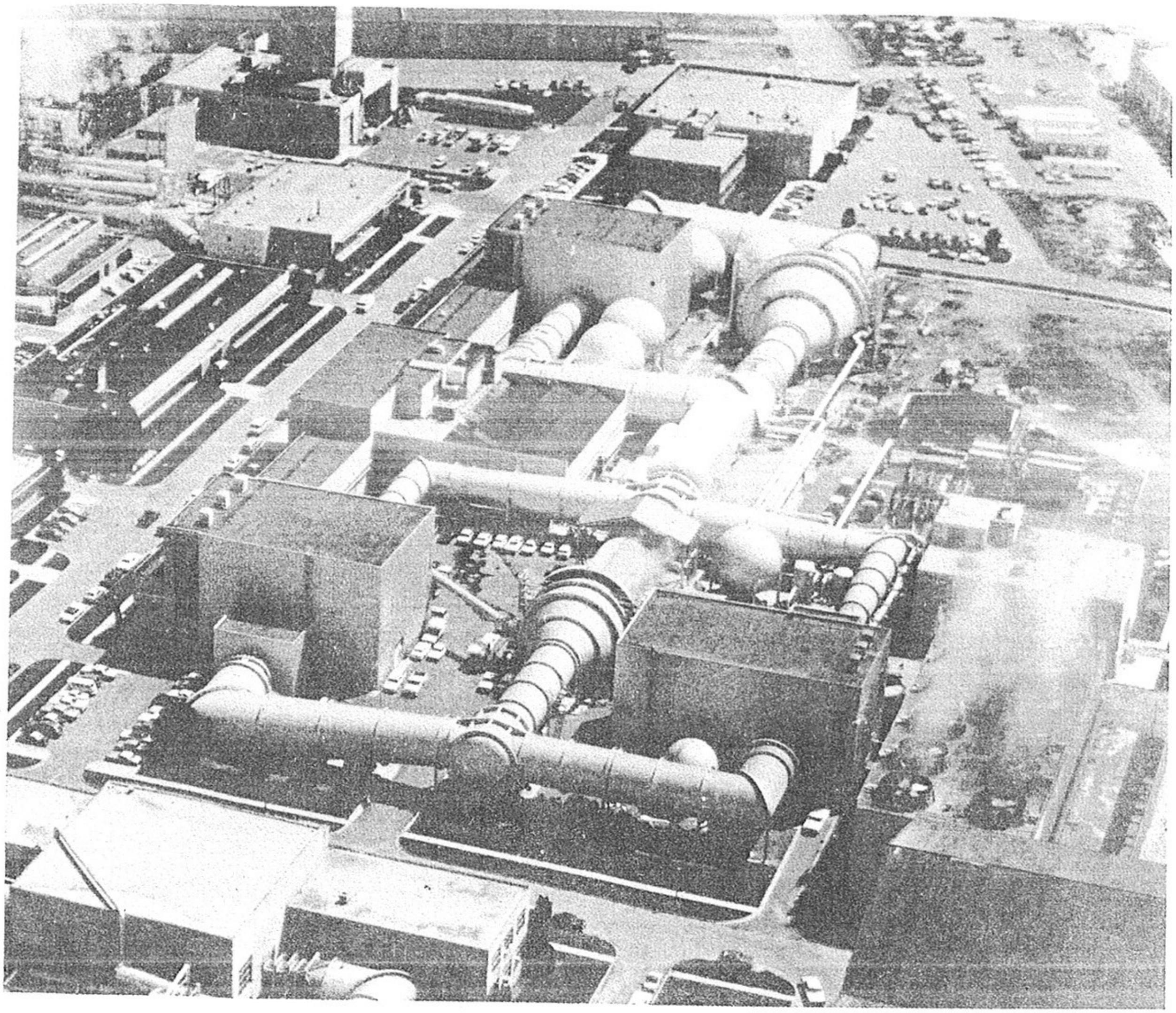
Helicopter and Powered-Lift Technology Division
Low Speed Wind Tunnel Investigations Branch
Jerry V. Kirk

LOCATION:

Building N-221

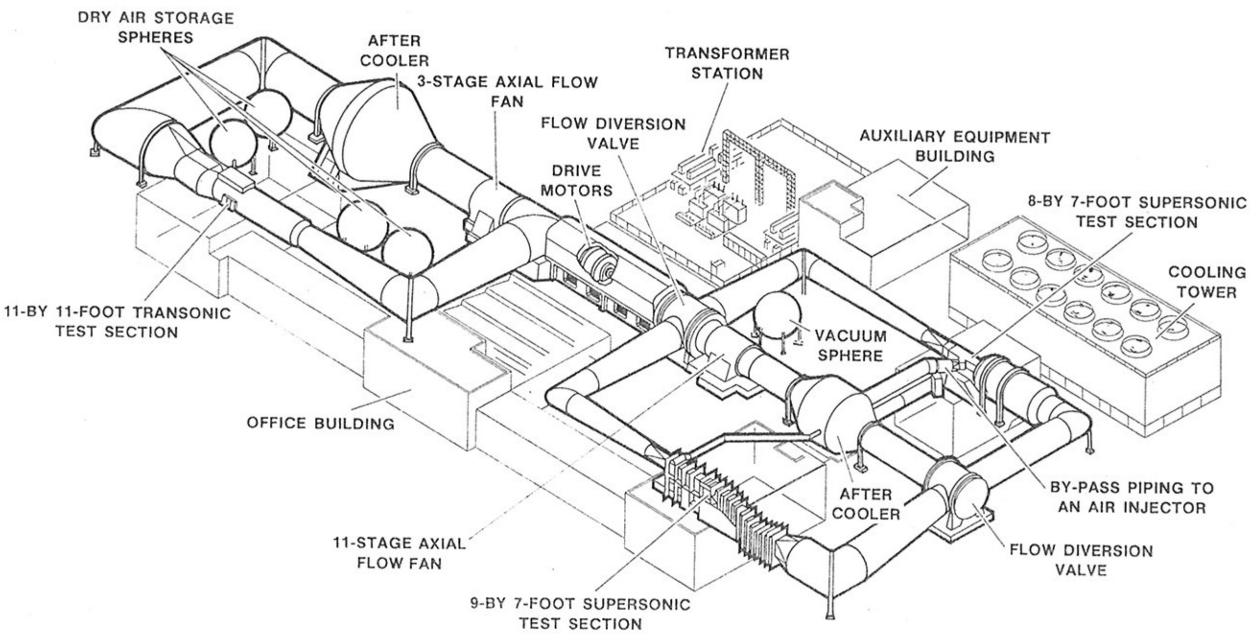


6. UNITARY PLAN FACILITY



6. UNITARY PLAN FACILITY

The Unitary Plan Facility, considered a landmark in the development of supersonic wind tunnels, is a unique system of wind tunnels comprised of three test sections: an 11- by 11-Foot Transonic Tunnel (Mach 0.40 to 1.40), a 9- by 7-Foot Supersonic Tunnel (Mach 1.55 to 2.50), and an 8- by 7-Foot Supersonic Tunnel (Mach 2.45 to 3.45), all capable of operating at variable stagnation pressures. The major common element of the tunnel complex is its drive system, consisting of four intercoupled electric motors that can provide 134.23 MW (180,000 hp) continuously.



STATUS:

Fully operational since 1956.

JURISDICTION:

Aerodynamics Division
Experimental Investigations Branch
Daniel P. Bencze

LOCATION:

Building N-227

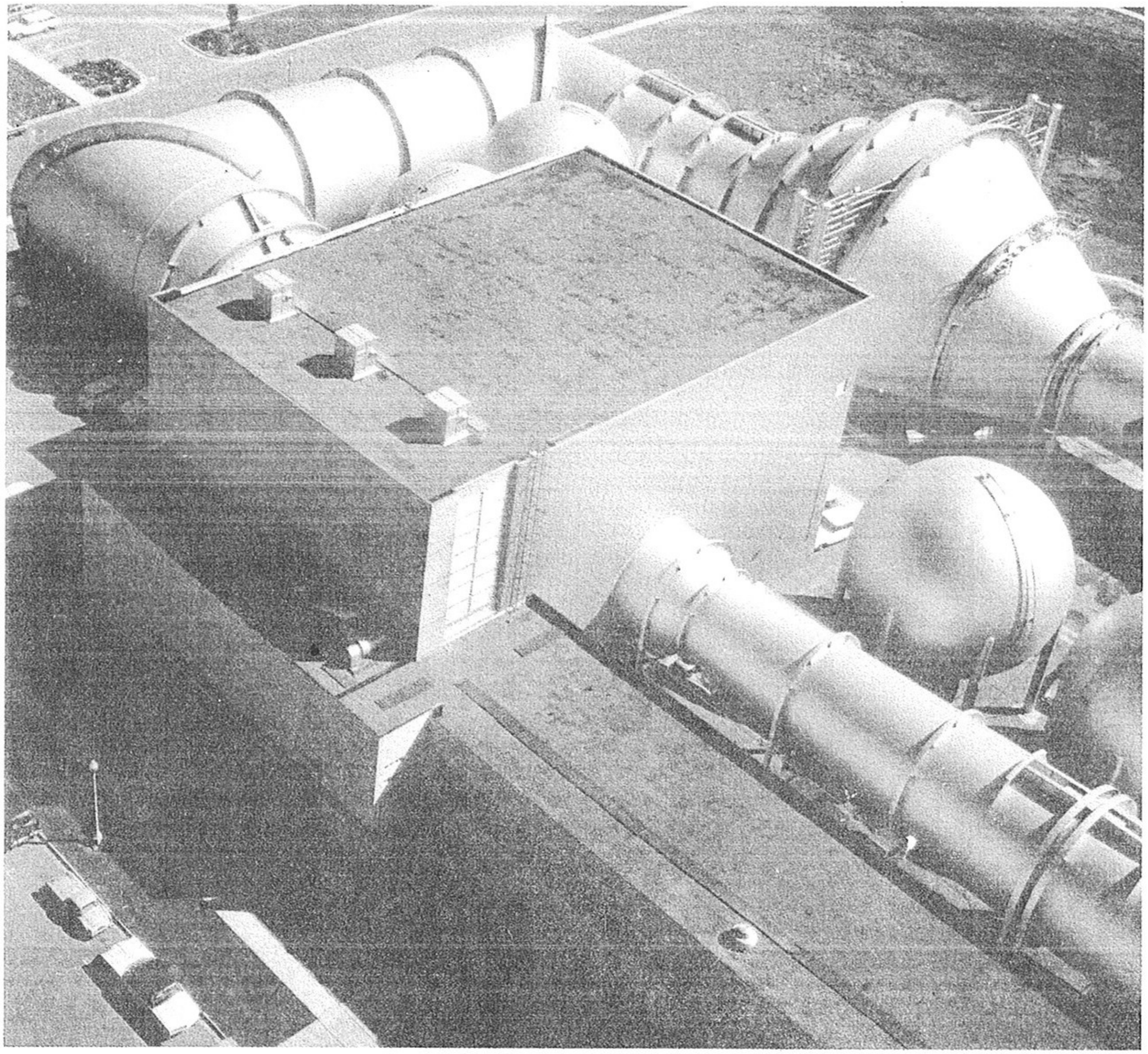
ADDITIONAL FEATURES

	Strut drive model support	Subfloor model support	3000-psi air system	3000-psi air heater
11X11 ft	yes	yes	yes	yes
9X7 ft	yes	no	yes	yes
8X7 ft	yes	no	yes	no

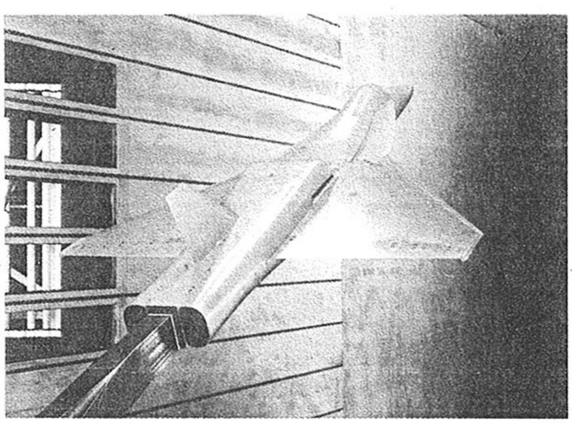
Unitary Plan Tunnels

Unitary test sections	Height and width, m (ft)	Speed range, M	Stagnation pressure, mb (psia)	Stagnation temperature, K (°R)	Reynolds number, per m (ft)	Dynamic pressure, mb (psf)	Special features
11-Foot Transonic	3.35X3.35 (11X11)	0.40 to 1.4	507 to 2280 (7.3 to 33.1)	322 (580)	5.58 to 30.84X 10^6 (1.7 to 9.4X 10^6)	120 to 958 (250 to 2000)	Slotted test section, 4 walls
9- by 7-Foot Supersonic	2.74X2.13 (9X7)	1.55 to 2.5	304 to 2027 (4.4 to 29.4)	322 (580)	4.92 to 21.32X 10^6 (1.5 to 6.5X 10^6)	96 to 694 (96 to 479)	See page 18
8- by 7-Foot Supersonic	2.44X2.13 (8X7)	2.45 to 3.5	304 to 2027 (4.4 to 29.4)	322 (580)	3.28 to 16.40X 10^6 (1.0 to 5.0X 10^6)	96 to 479 (200 to 1000)	See page 20

6a. 11- BY 11-FOOT TRANSONIC WIND TUNNEL

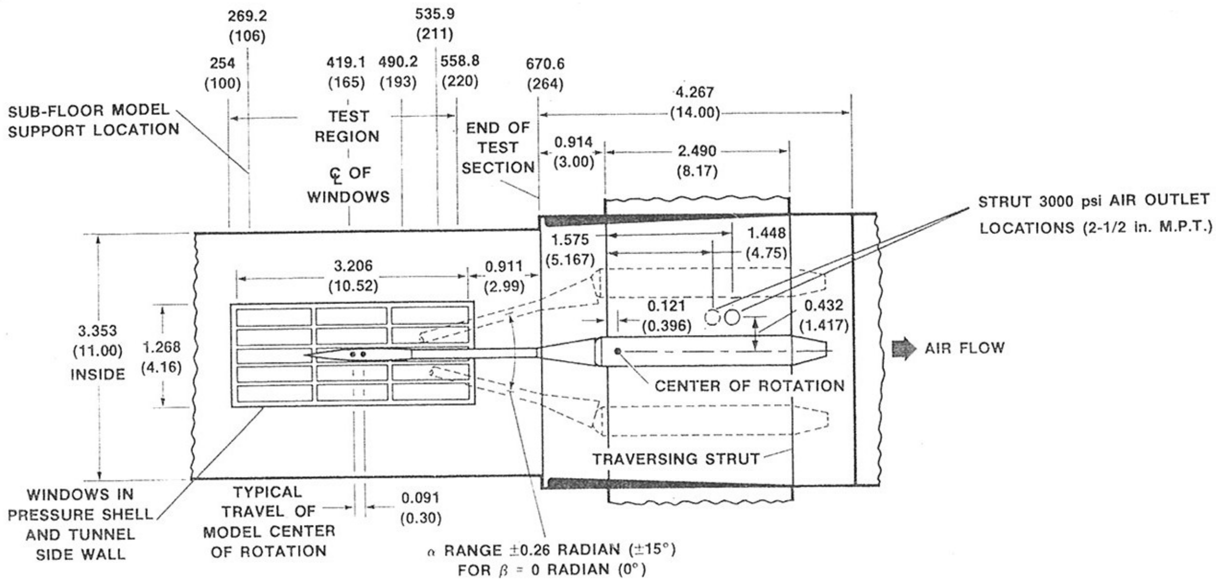


6a. 11- BY 11-FOOT TRANSONIC WIND TUNNEL



The 11- by 11-Foot Transonic Wind Tunnel is a closed-return, variable density tunnel with a fixed geometry, ventilated throat, and a single-jack flexible nozzle. Airflow is produced by a three-stage, axial-flow compressor powered by four wound-rotor, variable-speed, induction motors. For conventional steady-state tests, models are generally supported on a sting. Internal strain-gage balances are used to measure forces and moments. (Additional facilities are available for measuring multiple steady or fluctuating pressures.) A schlieren system is available for studying flow patterns, either by direct viewing or by photographs, as well as a system for obtaining 51X101 cm (20X40 in.) shadowgraph negatives.

TEST SECTION STATIONS IN CENTIMETERS (INCHES)



NOTE: ALL DIMENSIONS ARE IN meters (ft) UNLESS OTHERWISE NOTED.

PERFORMANCE:

Mach number (continuously variable) . . . . 0.4 to 1.4
Stagnation pressure, mb (psia) . . . . 507 to 2280
(7.3 to 33.1)
Reynolds number . . . . 5.58×10^6 to 30.84×10^6/m
(1.7×10^6 to 9.4×10^6/ft)
Stagnation temperature, K (°R) 322 (580)

DIMENSIONS OF TEST SECTION, m (ft):

Height 3.35 (11.0)
Width 3.35 (11.0)
Length 6.70 (22.0)
Access . . . . Top hatch: 2.13×6.70 (7.0×22.0)

STATUS:

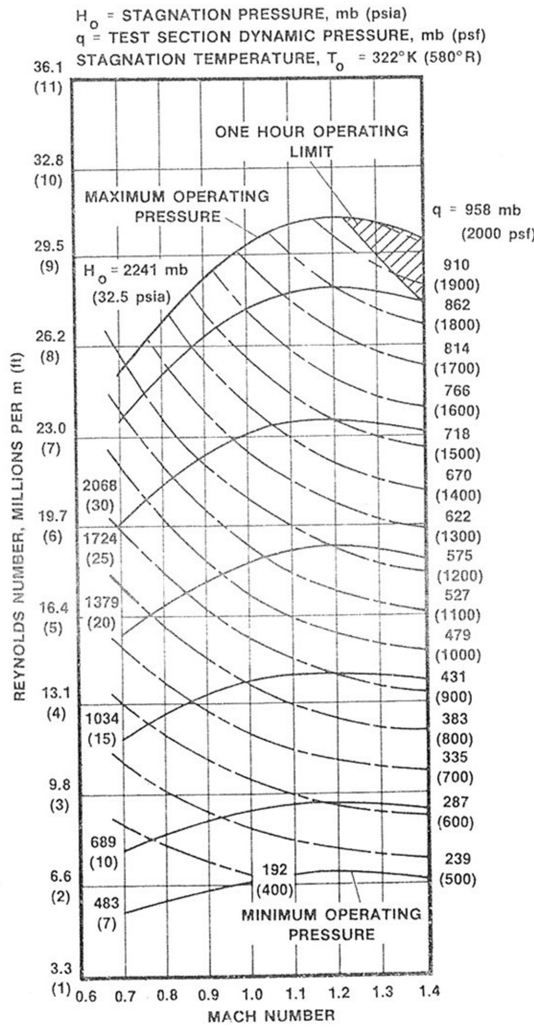
Operational since 1956

JURISDICTION:

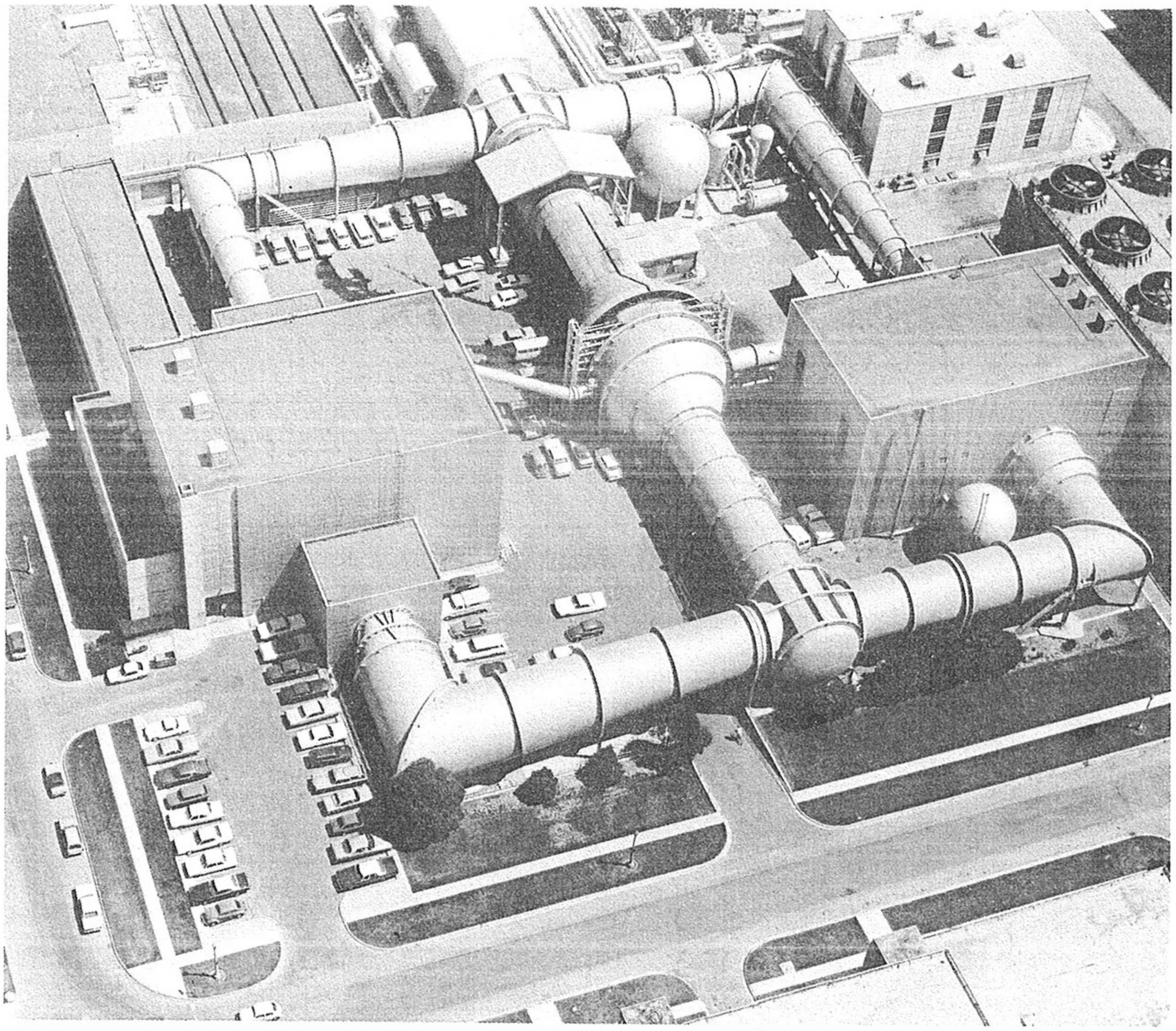
Aerodynamics Division
Experimental Investigation Branch
Daniel P. Bencze

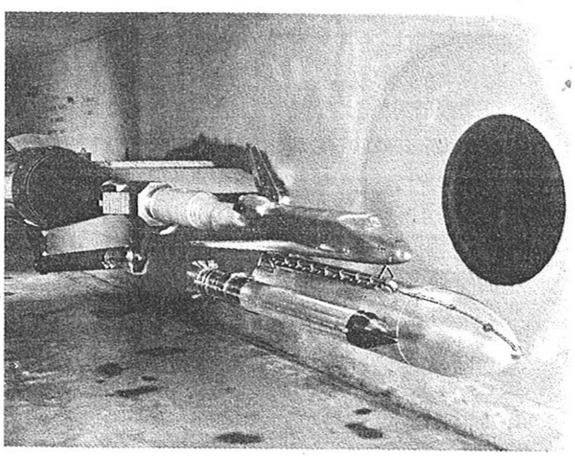
LOCATION:

Building N-227A



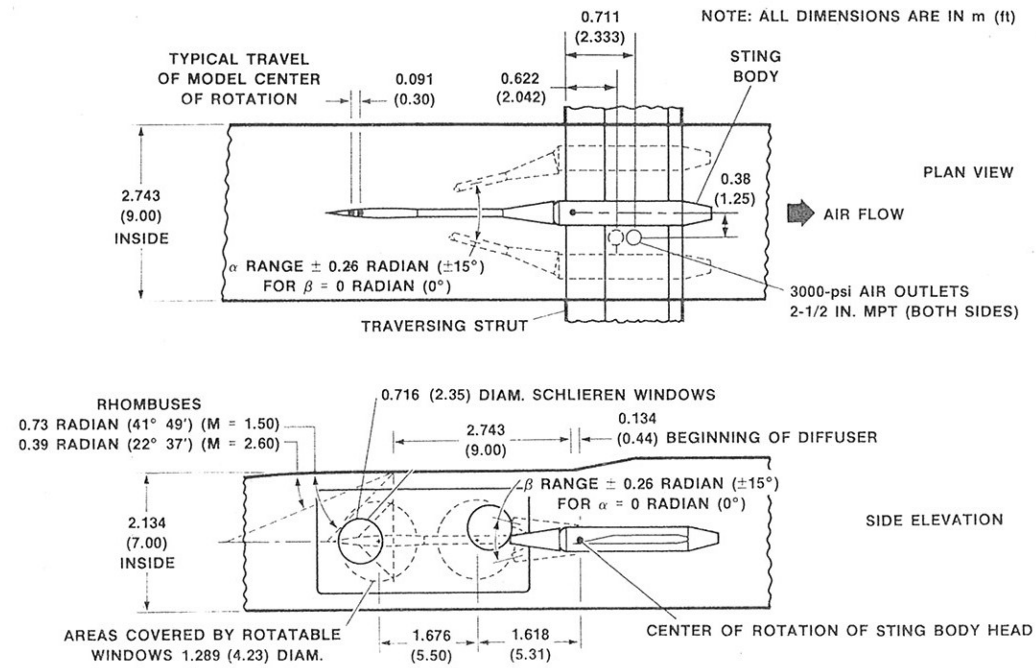
6b. 9- BY 7-FOOT SUPERSONIC WIND TUNNEL

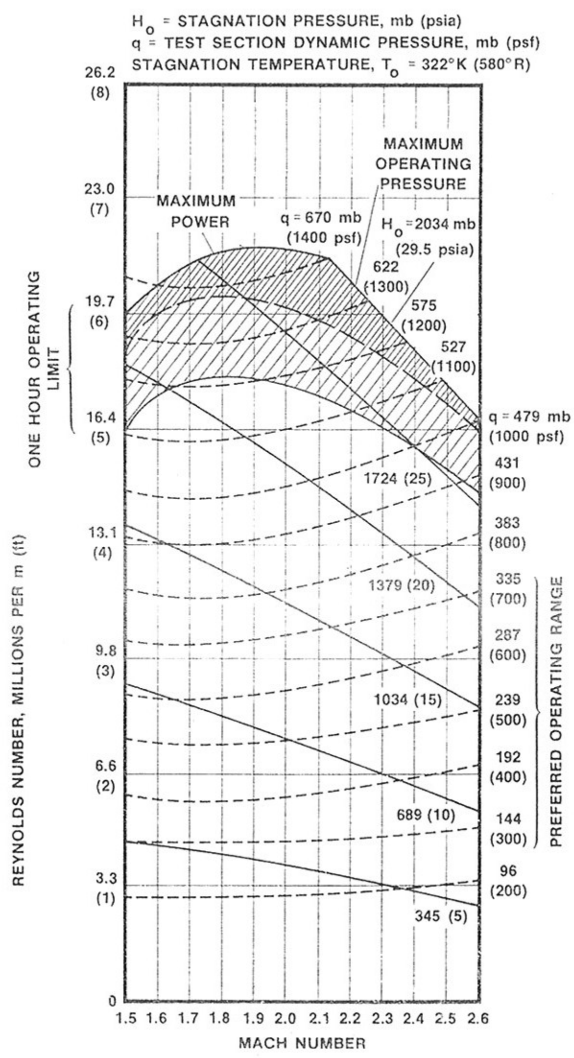




6b. 9- BY 7-FOOT SUPERSONIC WIND TUNNEL

The 9- by 7-Foot Supersonic Wind Tunnel is a closed-return, variable-density tunnel equipped with an asymmetric, sliding-block nozzle. The test section Mach number can be varied by translating, in the streamwise direction, the fixed contour block that forms the floor of the nozzle. Airflow is produced by an 11-stage, axial-flow compressor powered by four variable-speed, wound-rotor, induction motors. For conventional, steady-state tests, models are generally supported on a sting. Internal strain-gage balances are used to measure forces and moments. (Additional facilities are available for measuring multiple steady or fluctuating pressures.) A schlieren system is available for studying flow patterns, either by direct viewing or by photographs, as well as a system for obtaining 51X51 cm (20X20 in.) shadowgraph negatives.





PERFORMANCE:

Mach number (continuously variable) . . . . . . 1.55 to 2.5
Stagnation pressure, mb (psia) . . . . 304 to 2027 (4.4 to 29.4)
Reynolds number . . . . 4.92×10^6 to 21.32×10^6/m (1.5×10^6 to 6.5×10^6/ft)
Stagnation temperature, K (°R) 322 (580)

DIMENSIONS OF TEST SECTION, m (ft):

Height 2.13 (7.0)
Width 2.74 (9.0)
Length 5.49 (18.0)
Access . . . . Top hatch: 1.83×2.74 (6.0×9.0)
Side door: 0.91×1.98 (3.0×6.5)

STATUS:

Operational since 1956

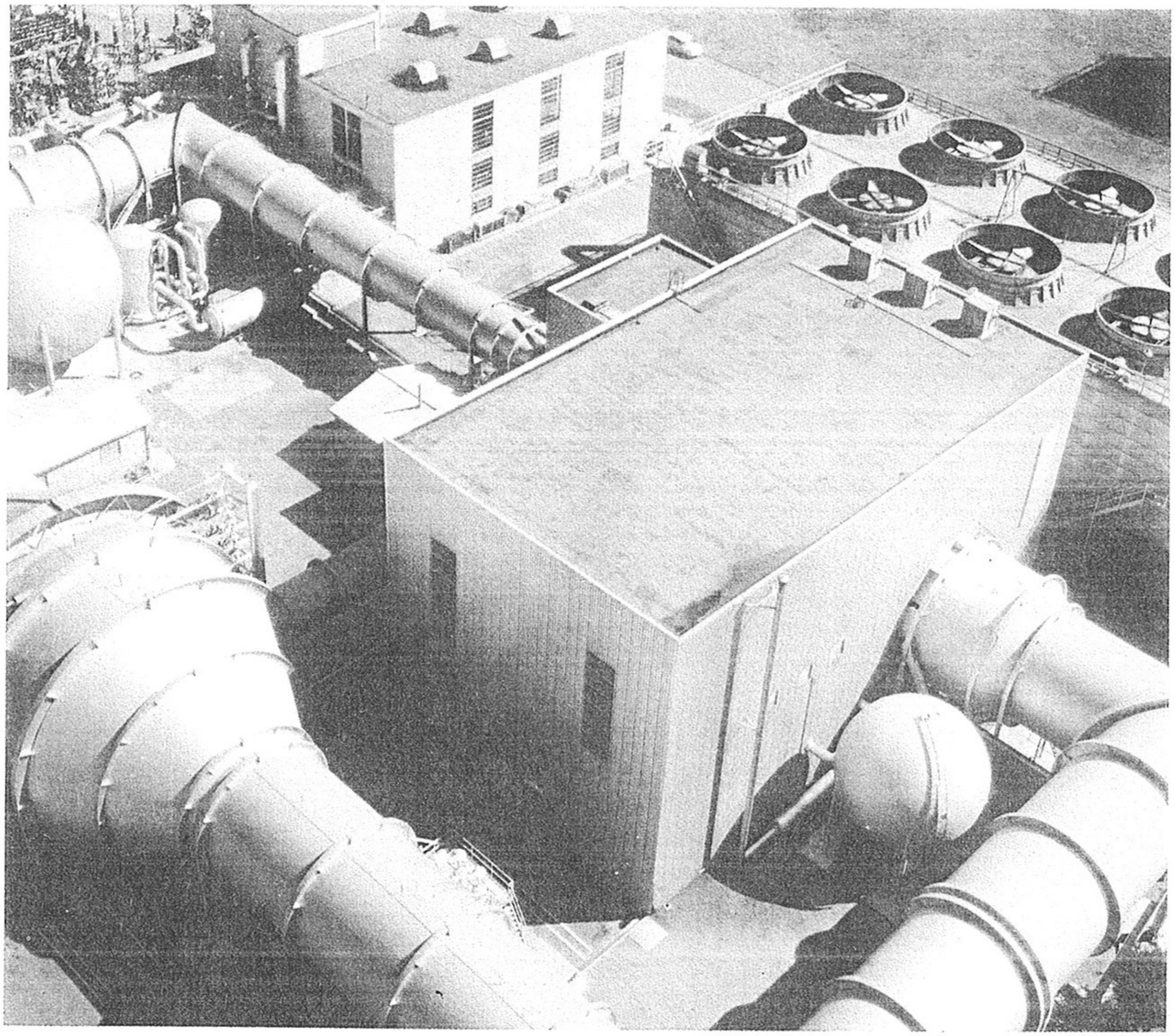
JURISDICTION:

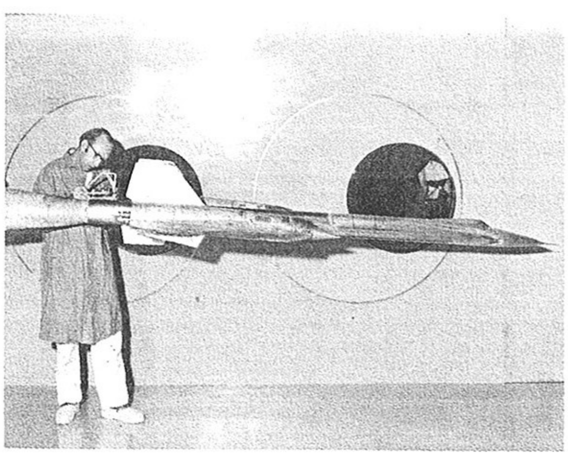
Aerodynamics Division
Experimental Investigations Branch
Daniel P. Bencze

LOCATION:

Building N-227B

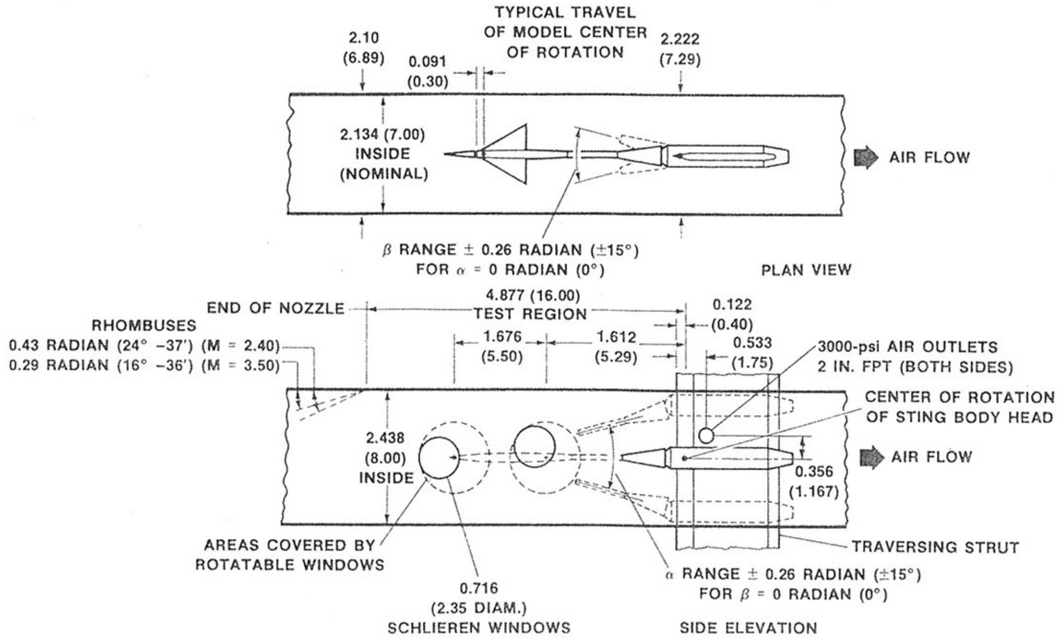
6c. 8- BY 7-FOOT SUPERSONIC WIND TUNNEL



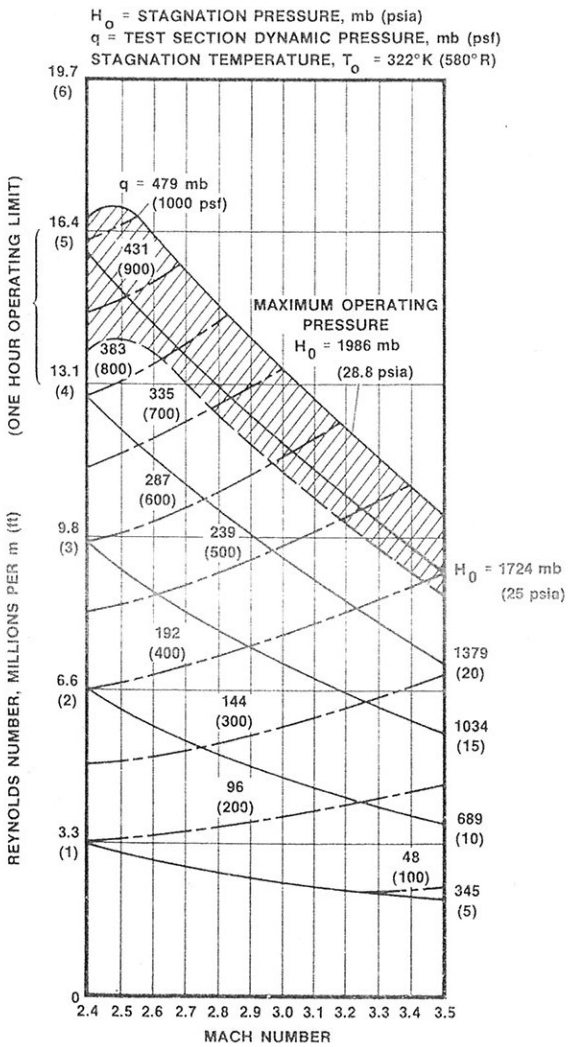


6c. 8- BY 7-FOOT SUPERSONIC WIND TUNNEL

The 8- by 7-Foot Supersonic Wind Tunnel is a closed-return, variable-density tunnel equipped with a symmetrical, flexible-wall throat (the side walls are positioned by a series of jacks operated by hydraulic motors). The upper and lower surfaces are fixed. Airflow is produced by an 11-stage, axial-flow compressor powered by four variable-speed, wound-rotor, induction motors. For conventional, steady-state tests, models are generally supported on a sting. Internal strain-gage balances are used to measure forces and moments. (Additional facilities are available for measuring multiple steady or fluctuating pressures.) A schlieren system is available for studying flow patterns, either by direct viewing or by photographs, as well as a system for obtaining 51X51 cm (20X20 in.) shadowgraph negatives.



NOTE: ALL DIMENSIONS ARE IN meters (ft)



PERFORMANCE:

Mach number (continuously variable) . . . . . . 2.45 to 3.5
Stagnation pressure, mb (psia) . . . . 304 to 2027 (4.4 to 29.4)
Reynolds number . . . . 3.28×10^6 to 16.40×10^6/m (1.0×10^6 to 5.0×10^6/ft)
Stagnation temperature, K (°R) 322 (580)

DIMENSIONS OF TEST SECTION, m (ft):

Height 2.44 (8.0)
Width 2.13 (7.0)
Length 4.88 (16.0)
Access . . . . Top hatch: 0.61X1.37 (2.0X4.5)
Side door: 2.44X3.05 (8.0X10.0)

STATUS:

Fully operational since 1956

JURISDICTION:

Aerodynamics Division
Experimental Investigations Branch
Daniel P. Bencze

LOCATION:

Building N-227C

Supplemental Information on Selected Properties: 36% Scale Model of the Space Shuttle Orbiter; N-229; N-240/N-240A; and N-258

Evaluation of Historic Resources Associated with the Space Shuttle Program at Ames Research Center

Supplemental Information on Selected Properties:

36% Scale Model of the Space Shuttle Orbiter
N-229
N-240/N-240A
N-258

Prepared By:

Dr. Ann Clarke
Roger Ashbaugh

Draft: 13 February 2007

36% Scale Model of the Space Shuttle Orbiter

Normally, in aeronautical R&D, wind tunnel tests using models would be followed by development of the vehicle and extensive flight tests prior to certification. Because the Space Shuttle Orbiter is a large, very sophisticated and very expensive glider, engineers could not use conventional flight testing. Further, high speed computers such as those at N-258, were not available at the time to simulate flight testing.

Because of these limitations, the Shuttle Program undertook an extensive wind tunnel test program using scale models. The purpose of the wind tunnel test program using scale models was to provide confidence in the aerodynamic predictions within specified tolerances and insure the Orbiter would have acceptable flight characteristics. The Shuttle Program constructed at Ames a set of models at different scales. To most closely approximate the Orbiter and minimize unknowns from scale effects, the set included the largest scale model that could be tested in the largest wind tunnel available. The largest scale model produced at Ames, the 36%, weighed 24 tons, spanned 44 feet in length, and cost $1 million in 1975. Using the 36% scale model in the 40- by 80-ft Wind Tunnel at Ames at conditions most closely simulating flight Reynold's number, engineers collected 250 hours of test data during a seven-day-per-week, two-shift-per-day period. The wind tunnel test data allowed the Shuttle Program to proceed and conduct a total of 30 minutes of flight testing in which the Shuttle Enterprise was released from an L1011 at 37,000 feet and observed during descent and landing. Without the scale model testing, the flight testing necessary for certifying the Orbiter for human flight could not have occurred.

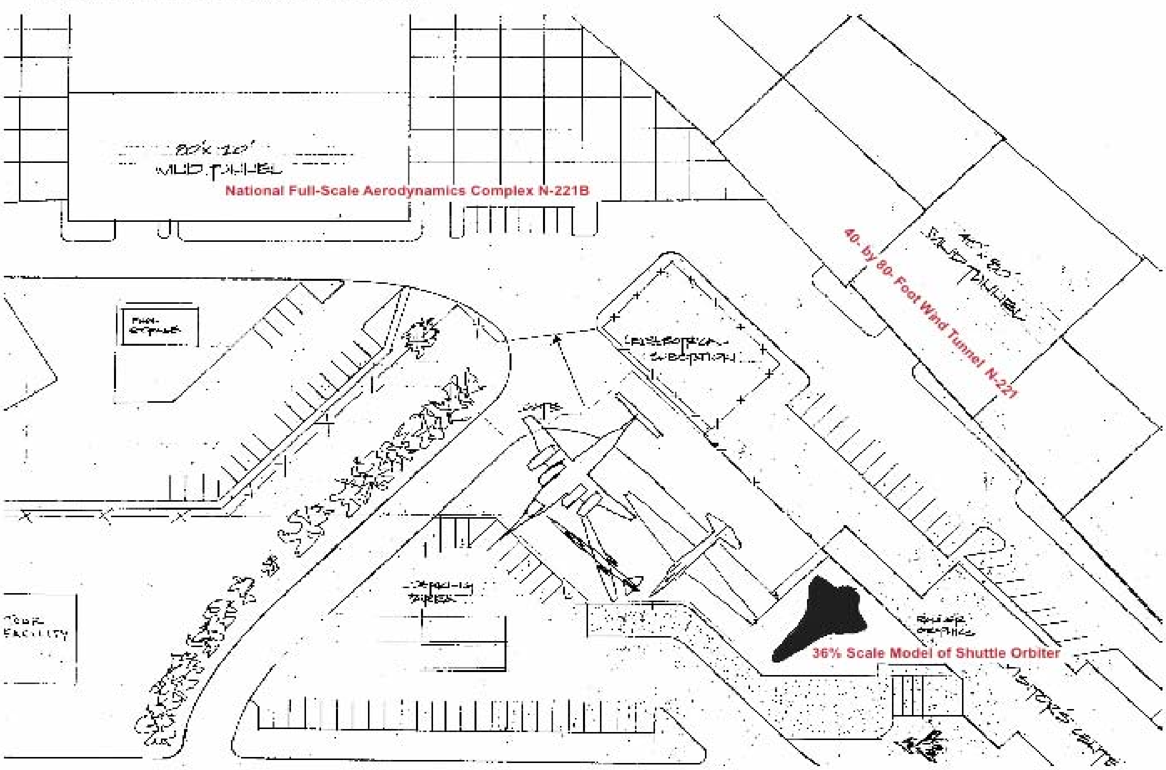
Development of the Orbiter's Thermal Protection System (TPS) required a major effort, according to Milton A. Silveira, deputy manager of the orbiter project office at NASA's Johnson Space Center. The 36% scale model was essential to testing the Shuttle's TPS. Unlike the Apollo Program, the Shuttle Program required that the TPS withstand multiple launch and re-entry operations. The Apollo Program had used an ablative and smooth surfaced TPS. The Shuttle Program had developed a new TPS using tiles made of a brittle material and set such that the grooves left between them would minimize flexure and thereby avoid undue stress. The tiles and their placement created a rough surface on the Orbiter.[1] However, the aerodynamic effects of this rough surface were unknown. Extensive flight testing was not feasible and high speed computers such as the those now located at the N-258 were not available.

To test the Orbiter's TPS, engineers covered the 36% model with tiles of plastic foam, cut to scale and interspersed with grooves of proper depth and width. One of the major arguments for using the 36% scale model was that at smaller scales, precise simulation of the new TPS became much more difficult.[2] After the wind tunnel testing, the Shuttle Program initiated a flight test program using a full-scale Orbiter, the Enterprise, now on display in a hangar at the Udvar-Hazy Center of the Smithsonian National Air and Space Museum. The flight test program for the Orbiter was unique to flight testing at the time because less than 30 minutes of flight test time, considered an extremely short amount, was conducted. This short amount of flight test time was made possible through extensive wind tunnel testing of the 36% model which provided reliable data predicting flight characteristics that closely matched performance data.

NASA produced five technical reports on the Orbiter model tests: *Aerothermodynamic data base; Data File Contents Report* (NASA-CR-171807); *Results of tests using a 0.36-scale model (76-0) of the Space Shuttle vehicle orbiter in the NASA/Ames Research Center 40 by 80-foot subsonic wind tunnel (0A100). Volume 1*(NASA-CR-167364) and *Volume 2* (NASA-CR-167365); *Results of tests using a 0.36-scale model (76-0) of the Space Shuttle orbiter vehicle 101 in the NAS/Ames Research Center's 40x80-foot subsonic wind tunnel (0A174), Volume 1* (NASA-CR-167340, and Volume 2 (NASA-CR-167341). The AIAA published a paper *"The Space Shuttle Orbiter approach and landing tests- A correlation of flight and predicted performance data."* (AIAA Paper 78-793).

Later, the Orbiter 36% model was placed on a truck bed and toured the U.S. NASA shipped it to the Paris Air Show and then delivered it to Marshall Space Flight Center. Eventually, NASA returned the 36% model to Ames where it was refurbished and placed on a display stand outside of the 40- by 80-ft Wind Tunnel.[3] The model was located next to a new outdoor amphitheater near the Ames Visitor's Center in the shadow of the still active 40- by 80-ft Wind Tunnel and was used to inform visitors and students about the Shuttle Program and the role of the testing program at Ames. The educational facility has since been relocated and the future of the 36% model is uncertain.[4]

Site Plan Showing Spatial Relationship of 36% Scale Model of Shuttle Orbiter to N-221 and N-221B NFAC



Resources:

[1] Richard G. O'Lone, Aviation Week and Space Technology, "Tunnel Tests Yield New Orbiter Data", June 30, 1975, page 43,44.
[2] Ibid.
[3] Donald James, Project Manager for Installation of the Model, Ames
[4] Keith Venter, Historic Preservation Officer, Ames

N-229

The Experimental Fluid Dynamics Facility N-229 features the 3.5-Foot Wind Tunnel comprised of a pebble-bed heater, control room, nozzles, wind tunnel test section, and diffuser and was used for high temperature testing of the STS and Orbiter using 1.5% scale models in speed ranges up to Mach 10. The tunnel was capable of running continuous tests of from 3 minutes to 10 minutes. The tests primarily examined STS at high speed in angle of attack for initial entry, and interaction during ascents with and without solid rocket boosters and the external tank. Test results were captured in both digital data form and shadowgraphs using cameras. Currently, all parts of the equipment comprising the 3.5-Foot Wind Tunnel remain in the N-229 facility with some in a dismantled state, with the exception of the data control and systems control equipment which have been removed. There have been no alterations to the exterior of the N-229 building in the period of time since the 3.5-Foot Wind Tunnel was last operated for the Shuttle Program. If the tunnel parts were reassembled, the property could be reactivated and could therefore be reconsidered for nomination.

Interviewees:
Scott Edelman, Deputy Chief, Thermophysics Facilities Branch, Ames

N-240/N-240A

For purposes of the discussion of the role of N-240 and N-240A, the Orbiter as a component of the space transportation system can be likened to a commercial truck. The Orbiter as truck provided a reusable platform for payloads, much as a glazier's truck or plumber's truck provides racks for sheets of glass or tools. However, unlike a glazier's truck or plumber's truck on Earth, the interface between the payload systems and the Orbiter systems had to be exact to avoid contamination of the Orbiter environment for the astronauts while allowing the astronauts to conduct the R&D on intricate instruments under controlled conditions.

Three NASA Centers engineered the design, fabrication, integration, testing, and verification of payloads for the Orbiter prior to shipment to KSC. Each Center also provided for the initial 2 - 3 years of training on interfacing with the payloads associated with a specific mission. Ames was responsible for all animals, cells, tissues, and plants payloads, MSFC for materials research payloads, and JSC for human-centered research payloads.

Ames designed, fabricated, integrated, and tested research payloads flown on at least 56 Shuttle missions from 1984 to 2006 and half the payloads for 6 major spacelabs with unequivocal success rate. The Ames work was carried out primarily in N-240 and N-240A, utilizing satellite facilities such as the N-236 science building, the N-211 fabrication shops and N-239A centrifuges. N-240 was modified from its prior use as a Space Environment Research Facility to support verification of the payloads that were engineered, assembled, and integrated in N-240A which had been added to N-240 for this specific purpose. At least 75 astronauts trained for 2 to 3 years each at Ames on how to work on the payloads in a weightless environment. Training on the Vertical Motion Simulator also located at Ames would co-occur with the payload training.

The design, fabrication, and testing of the small payloads was a collaborative effort among the scientists, the mission crew members, and the engineers who designed the payload modules. Examples of engineering challenges addressed in the work carried out in N-240 and N-240A included re-design of the gloves in the glovebox to accommodate a variety of hand sizes while providing for dexterity sufficient to operate intricate instrumentation and live organisms and maintain controlled conditions. Another example was to develop a solution for mechanical feeding of the animals without creating backflow of fecal material and waste food into the Orbiter. A third example was to create and test state–of-the-art engineering systems to provide separation of the life support systems between the animal specimens and the crew members. On April 29, 1985, for the first time in U.S. history, two Squirrel Monkeys and 24 albino rats were launched into space aboard NASA's Spacelab Mission 3 in the Research Animal Holding Facility, designed by the Life Sciences Program at NASA Ames Research Center. The payloads were designed to the precise tolerances of the Shuttle to assure no cross contamination of the air shared by the astronaut crew under changing conditions of temperature and pressure.

In addition, the animal-based experiments of the life sciences element of the Fundamental Biology Program at Ames, headquartered in N-240/N-240A and at one time part of the Space Shuttle Program, was to provide models of the human physiological system in space under conditions available or which could be controlled in the Shuttle

Transportation System. The activities at Ames in N-240 and N-240A, coupled with similar activities at JSC and MSFC, to assure precise engineering, training, and management of payloads for transport and implementation on the Orbiter platform uniquely contributed to extending the knowledge and understanding required for astronauts to effectively function as an essential element in the operation of the Space Shuttle Transportation System. More than 400 scientific and engineering papers resulted from the work at Ames alone, improving understanding of the risks to human spaceflight that have and will continue to influence design and operation of the Orbiter and its successors. Spinoffs include new knowledge in medicine and public health. For example, bone loss is a major limitation not only to astronauts during extended spaceflight but also to people generally as they age.

Interviewees:

Bonnie Dalton, Deputy Director, Science Directorate, NASA Ames Research Center (responsible for construction and design input for labs and offices in 240A, which was finished in 1982. Also served as Branch Chief for payload operations, which was responsible for integration, crew training, and mission ops and was Payload Manager for Ames element of SLS-1. All payload managers were part of this branch).

N-258

The N-258 facility was built to provide a highly secure platform to support and continuously upgrade NASA's fastest and most powerful computer system. Computer science experts located at the N-258 facility assist in developing computer applications and facilitating their use of those applications by analysts networked nationwide into the N-258 computer.

Following the Space Shuttle Columbia accident, the CAIB report identified "*the need for the agency to manage risk using the most advanced and versatile techniques at our disposal"* (CAIB, p. 207). In response, the Space Shuttle Program evaluated a number of tools and selected two Ames developed tools for further development and application to the Shuttle: 1) Debris Transport Tool and 2) Damage Assessment Tool. The development and implementation of these tools significantly advanced the ability to predict aerodynamic loads for the Shuttle during ascent and provide enabling technology for accurately assessing any debris released during ascent and the analysis of any damage to the Shuttle prior to reentering the Earth's atmosphere. These tools, developed specifically for Return to Flight (RTF), are integrated into the Space Shuttle Program's standard operating procedures and have significantly advanced the field of computational fluid dynamics in aeronautics.

N-258, shortly after the CAIB report was published, housed the SGI Altix-Columbia Supercomputer, which has 20 superclusters (SGIRMk Altix 3700). Typically five of these clusters are available for RTF analysis efforts. During a Mission, five are reserved specifically for flight support with a second five clusters made available should a major problem arise. The high speed capabilities of this unique facility are critical for the quick response needed for both the Debris Transport Analysis/Ascent Aerodynamic Model (DTA) and the thermal analysis Damage Assessment Tool (DAT). The Debris Transport model has over 85 Million Grid Points in 569 Zones. Massive in its complexity, each analysis case requires between 2500 and 4000 CPU hours to reach a solution. Millions of load cases simulating speeds from liftoff to Mach 3.5 are run in support of RTF. Debris (foam, ice, grease, nuts, bolts, etc.) are modeled each with individual aerodynamic characteristics. The program defines the cone of influence each piece of debris may travel, whether it impacts the Shuttle, and the estimated kinetic energy on impact. This tool estimates the maximum allowable mass and kinetic energy that may be released from the "Shuttle Stack" during ascent without causing critical damage to the Orbiter.

During the first Return To Flight mission in 2006, support for the Space Shuttle Discovery STS-121 included the combination of the "Columbia Supercomputer", the experts in N-258, and the Ames engineering specialists linked to analysts in the Shuttle Program. From the moment of launch to the clearance of the Shuttle for safe reentry, this unique tool provided information to predict the risk to Discovery and its crew. Specifically, the near real time calculations were used to reduce uncertainties in the engineering models, validate observed debris release and possible strikes on the Shuttle. Because the Debris Transport Tool is customized to the shape of the Shuttle Orbiter, it will be retired with the Orbiter. However, current programs such as MSL and Orion request the use of these tools in the development and operational phases or their programs.

The Shuttle Program used the Damage Assessment Tool to evaluate debris damage to the Thermal Protection System (TPS) and predict pressure loadings and possible catastrophic reentry problems on an anomaly in the gap filler in the TPS, and develop mitigation. This analysis prompted Shuttle Program mission planners to develop an impromptu space walk to remove gap fillers and clear Discovery for reentry and landing.

Debris impacts can lead to failure of the TPS resulting in failure of the Orbiter during reentry and landing. Therefore, if analysts using the Debris Transport Tool at the supercomputer in N-258 determine a high probability that debris from the Orbiter will impact the Orbiter, they will use the Damage Assessment Tool to estimate critical reentry heating problems on any part of the Shuttle Orbiter and calculate potential damage across the full range of aerodynamic forces likely to be encountered. Damage assessments give Shuttle Program managers critical near real time information about the safe reentry condition of the Shuttle Orbiter while in flight.

Damage assessments were previously not available except after a mission. Today, in addition to providing in-flight assessments, the Shuttle Program uses the Debris Transport Tool and the Damage Assessment Tool at N-258 to set the parameters for further testing of selected Orbiter materials and optimizing test set conditions in the 9- By 7-Foot Wind Tunnel, the 11-Foot Wind Tunnel, The Arc Jet Laboratory, and the Hypervelocity Free Flight Aerodynamic Facility at NASA Ames. This capability saves critical resources by reducing the time and cost of wind tunnel and gun tests by narrowing the field of investigation to critical areas of interest. The Damage Assessment Tool has direct applications to and is currently used by the MSL, Orion and other programs that are associated with entering planetary atmospheres.

Further, in post-flight inspection of the Orbiter, the Shuttle Program can assess any surface anomaly using a post-flight inspection tool developed at Ames. This tool employs sensors to develop a 3-d image of the damage for incorporation into follow-up analyses for thermal analysis using the DAT on the Columbia Supercomputer in N-258. The Mold Impression Laser Tool (MILT) has a broader application to a number of projects and is directly transferred to all projects requiring arc jet testing such as Orion, MSL, etc.

The use by the Shuttle Program of both the Debris Assessment Tool and the Debris Transport Tool at the N-258 has reduced the time to do risk analysis on the Shuttle Orbiter from one week to eight hours, due largely to streamlined processes designed by the supercomputer experts and the speed of the unique Columbia Supercomputer in N-258. The Shuttle Program provided $18 million in initial funding for Return to Flight analysis at Ames in the N-258 and continues to fund work approximately $7 to $10 million annually for Shuttle Program support. The Shuttle Program recognized the importance of using the Debris Transport Tool and Damage Assessment Tool and is training Boeing contractors to use these tools as standard operating procedures for the Shuttle Program.

The combination of supercomputer experts and machines in N-258 with analysts networked in has created the fastest continuously operating supercomputer in the NASA system and facilitated expansion of the science of computational fluid dynamics in aeronautics. Of the 100 research papers created NASA-wide for Return to Flight of the Space Shuttle, 20 were on the science of computational fluid dynamics centered in

N-258.

Interviewees:
John Allmen, Project Manager, Return to Flight, Ames

N-258: NASA Advanced Supercomputing Facility

Location: 150 Allen Road, NASA Ames Research Center, Moffett Field, California

Date of Construction: 1986

Brief Description: N-258 is a two-story office and research building located at the corner of Allen Road and Parsons Avenue. The building is 87,340 square feet (8,114 square meters) in size. It features a concrete foundation, a concrete exterior with aluminum sash ribbon windows, and a flat roof. Its plan is configured into three square sections linked by a shared central connector. The building's exterior features chamfered edges and scored concrete panels. This building houses large supercomputers used for solving complex computational aerospace simulation problems.

Type/Function: Current use: NASA Advanced Supercomputing Facility (NAS); office and administrative facilities; research laboratories; computer and server facilities.

Historic Context: N-258 was dedicated in March 1987. Originally known as the Numerical Aerodynamic Simulation Facility, the building's name was changed to NASA Advanced Supercomputing Facility (NAS) in April 2001. NAS was established to act as a pathfinder in advanced, large-scale computing system capabilities through the use of the latest hardware and software technology and to house Ames' supercomputers. In 2004, the NAS Division co-developed, with industry partners SGI and Intel, what was initially the fastest supercomputer in the world. Named Columbia, the supercomputer is a 10,240-processor SGI Altix supercluster. Columbia remains NASA's fastest supercomputer, and it is used by researchers at almost every NASA center.

NAS researchers and computer scientists were early adopters of many technologies and methodologies that became standards of research worldwide. Through collaboration and pioneering work in networking, visualization, and modeling and simulation, N-258 staff accelerated advancements in these areas. Using high-end scientific and engineering workstations coupled with high-speed networking and high-end computing resources enabled NAS to firmly establish its leadership in computational fluid dynamics (CFD). The ability to simulate fluid flows using numeric solutions on a computer played a key role in improving and enhancing Shuttle performance, reliability, and safety for more than two decades.

Since 1985, NASA researchers have been working to provide and improve a computational framework for design and analysis of the entire fuel supply system of a liquid rocket, including high-fidelity unsteady flow analysis. Success in this effort decreases design costs, improves performance and reliability, and provides aerospace vehicle developers with information such as transient flow phenomena at startup, impact of non-uniform flows, and impact on the structure. Beginning in 2002, the computational framework enabled by early expertise in CFD at N-258 was used to investigate the root cause of cracks in the Shuttle engine's fuel-line. In 2004, following the Columbia Shuttle accident, NAS CFD researchers participated in a NASA Engineering and Safety Center-sponsored independent technical assessment investigation of the Shuttle's fuel-line cracks. These results were combined with other analyses and then presented to the Shuttle Program as part of the agency's Return to Flight (RTF) efforts. Various computational models and visualizations have been developed at N-258, and time-accurate computations have been carried out using this framework to characterize various aspects of the flow field surrounding the flowliner in the Shuttle.

N-258 capabilities and resources also facilitated a redesign of the Space Shuttle Main Engine (SSME). Designed in the 1970s, the SSME is still the most sophisticated reusable rocket engine in the world. Since its initial design, NASA has continued to increase reliability and safety of Shuttle flight through a series of enhancements, including major design changes to the hot gas manifold and turbopump. Two enlarged ducts replaced the original three-duct hot gas manifold in the powerhead, considered the backbone of the SSME. The new two-duct design, facilitated with the use of Cray XMP and Cray 1 supercomputers housed at NAS, and CFD techniques developed by NAS researchers, enhanced overall engine performance and reliability. CFD analyses showed that the two-duct design reduced pressure gradients within the system, and lowered temperatures in the engine during operation, which reduces stress on the turbopump and main injector. After undergoing extensive testing, the newly designed powerhead made its first flight on Discovery's 20th mission (STS-70) in July 1995, and has been used in all subsequent Shuttle missions.

OVERFLOW, a computational fluid dynamics program developed in the early 1990s by N-258 researchers, is used for solving complex flow problems such as designing launch and reentry vehicles and has been applied to a number of Space Shuttle Launch Vehicle and Space Shuttle Orbiter issues over the past two decades. This CFD application has led to a better overall understanding of the aerodynamic loads on the Space Shuttle, and has served as the primary tool for verifying wind tunnel derived aerodynamic loads during ascent including Orbiter wing, payload bay door, and vertical tail loads.

Following the Shuttle flight STS-27R during which damage was incurred (launched and landed in December 1988); a precursor code to OVERFLOW was used to perform debris analysis. CFD results, which showed that only isolated potential debris sources existed on the vehicle, led to the determination that insulation and ice were the cause of the damage. This analysis has had a huge positive impact on the Space Shuttle Program, leading to increases in safety of flight by minimizing hazardous debris sources; reducing inspection time; minimizing damage on the next flight; and reducing changes to thermal protection system application procedures.

Throughout the 1990s, OVERFLOW was used to support the Shuttle Aerodynamic Loads Verification Program through CFD analysis of the Shuttle Launch Vehicle ascent aerodynamic loads environment. OVERFLOW solutions were used in conjunction with the flight data system, and provided data in areas not covered by flight instruments, yielding a cost savings of approximately $10M.

In response to the Columbia tragedy on February 1, 2003, the NAS Division employed state-of-the-art CFD codes to simulate steady and unsteady flow fields around Columbia during ascent. Simulation results prompted the use of a higher velocity and kinetic energy in foam impact testing done under the Columbia Accident Investigation Board, which showed massive damage to the Orbiter wing reinforced carbon-carbon panels and damaged T-seals due to foam impact. Simulations also provided insight into the mechanism of debris shedding from the bipod-ramp region. Each moving-body simulation required 1,000-5,000 processor hours running on a 1,024-processor SGI Origin supercomputer housed in N-258. Over a very short time period, more than 450 full simulations were run using about 600,000 processor hours.

During the Discovery mission in the summer of 2005, NAS Division researchers were on stand-by to provide debris transport analysis support using debris-transport software, which had been significantly improved by the NAS researchers, and was running on the Columbia supercomputer in N-258. Several incidences throughout the mission required NAS resources, including evaluation of the potential threat of ice forming on one of the solid rocket boosters/external tank aft attach struts, analyses of ice/frost ramp foam debris that were shed 155 seconds into the mission, and analyses of a torn 20 x 3 inch panel of the Advanced Flexible Reusable Surface Insulation blanket located under the commander's window on the Orbiter. Within hours, NAS researchers using N-258 computing resources and the debris-transport software were able to run debris simulations and deliver analyses alleviating concerns. Additional wind tunnel testing at Ames was coupled with the debris analysis software results to further minimize concern regarding the torn panel on Discovery.

Using N-258 resources has reduced the time to do risk analysis on the Shuttle from one week to eight hours, due largely to streamlined processes designed by NAS supercomputer experts and the Columbia supercomputer. The Shuttle Program recognized the importance of the capabilities provided by Ames and the NAS Facility and awarded $18 million in initial funding for RTF analysis. Continued Ames funding ranges from $7 to $10 million annually for Shuttle Program support, with a significant portion supporting research conducted by NAS researchers, which is enabled by computing resources housed in N-258.

National Aeronautics and Space Administration, NASA Facts:
NASA Ames Contributions to Return to Flight

NASA Ames Contributions to Return to Flight

After the loss of the space shuttle Columbia and crew on Feb. 1, 2003, NASA engineers and scientists turned their grief into a determined resolve to prevent a repeat of the tragic accident and to return the shuttle to safe flight.

For the past three years, NASA has tapped the wealth of knowledge and expertise within the agency to ensure the space shuttle's flight worthiness, astronaut safety and develop plans for in-flight contingencies ranging from minor tile damage to a major structural breach.

NASA Ames Research Center, located in California's Silicon Valley, is playing a vital role in the in NASA's space shuttle program.

NASA Ames personnel and facilities are involved several key aspects of the program, from the analysis of new space shuttle system designs to development of in-flight analysis tools; from improvements in thermal protection durability and repair to the analysis of large data sets used in

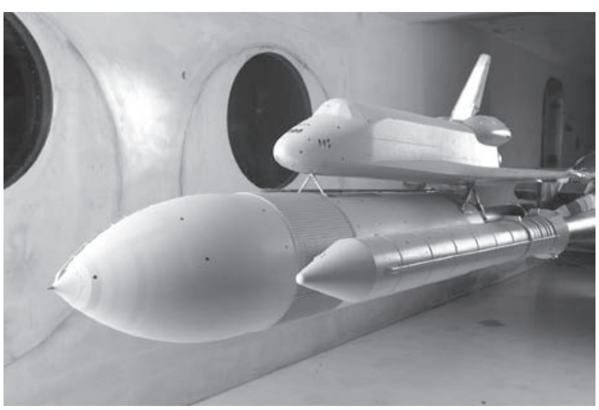
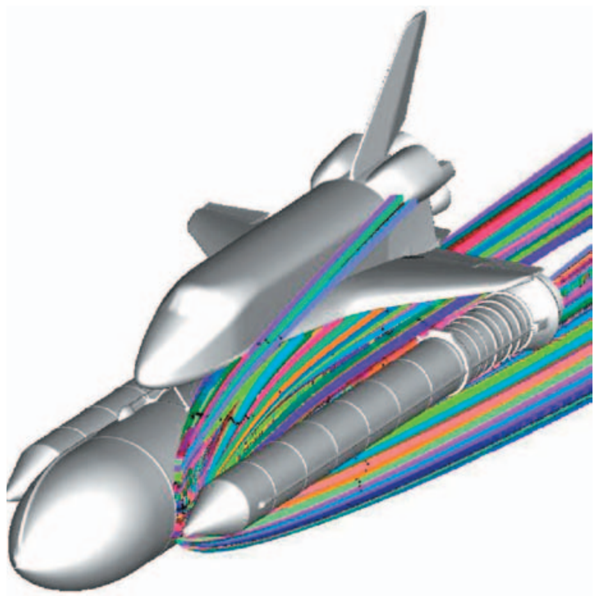


Photo of the 3 percent wind-tunnel model of the Space Shuttle in the NASA Ames Unitary Wind Tunnel.

complex simulations by one of the world's fastest supercomputer, the Columbia supercomputer.

The NASA Ames space shuttle effort taps into the center's critical core capabilities in computational fluid dynamics, information technology and thermal protection systems. These core capabili-



Plot of several trajectories depicting the path of debris shed from the External Tank generated by the Columbia.

ties meld the expertise acquired through decades of aerospace research and development with cutting-edge information technology and unique facilities.

Computational fluid dynamic (CFD) models are helping NASA develop design modifications to space shuttle systems, characterize debris flow patterns and understanding the conditions the shuttle's thermal protection system experiences during re-entry. The CFD models are being created and validated using a refurbished three percent space shuttle model in the center's 9-foot-by-7-foot supersonic wind tunnel. The model was built during the development of the original space shuttle design in the 1980s. NASA Ames' ballistic gun range, originally used in the past to develop Apollo capsule designs, was used to develop debris trajectory CFD models.

In preparation for the STS-121 flight, NASA Ames tests determined the aerodynamic effects on key shuttle components with the removal of the liquid hydrogen and liquid oxygen Protuberance

Repair panel heated in the arc jet stream of the NASA Ames Interaction Heating Facility.

Air Load (PAL) ramps. The tests also increased NASA's understanding of the forces exerted on the external tank foam including the unexpected areas of foam shedding on the STS-114 flight.

Using the center's Columbia supercomputer, engineers and scientists are compiling and analyzing the tremendous amounts of data collected from tests at Ames and at other NASA centers. Using this capability, NASA simulated various pre-launch, ascent, on orbit and descent conditions. Columbia simulated the trajectory of the foam shed on the STS-114 flight, increasing NASA's understanding of the behavior of foam debris. The Columbia super computer has simulated 60 shuttle scenarios using more than 100,000 computational hours. The speed of the computer continues to allow NASA to create and analyze simulations in a fraction of the time previously required. Other information technology expertise is helping NASA gather, organize and analyze information before, during and after space shuttle operations and monitor vehicle health.

As a recognized leader in thermal protection systems, Ames continues to use its expertise to develop increasingly durable thermal protection systems (TPS) and on-orbit TPS repair systems. Concepts for fixing cracks or holes include plugs (cover plates), patches (pre-ceramic polymers impregnated cloth) and paste-like materials (pre-ceramic polymers) are being assessed for effectiveness in the NASA Ames arc jet facility at up to 3000 degrees Fahrenheit to simulate re-entry conditions.

NASA Ames continues its integral role to provide on-going technical, scientific and engineering support for the space shuttle program. NASA Ames will continue to provide the critical data shuttle managers need during before, during and after a mission. NASA Ames personnel and facilities stand ready for the analysis of any in-flight situation and NASA's mission to explore the moon, Mars and beyond.

National Aeronautics and Space Administration

NASA Ames Research Center
Moffett Field, California, 94035

National Aeronautics and Space Administration, NASA Facts:
NASA Ames Entry Aero-heating CFD Analysis

NASAFacts

NASA Ames Entry Aero-heating CFD Analysis Ê

Background

In 2003, the Columbia Accident Investigation Board determined that foam debris striking the wing leading-edge upon ascent was directly responsible for the loss of the Space Shuttle Columbia and its seven crew members on February 1, 2003.

As part of its Return to Flight (RTF) efforts, NASA has developed a capability to image, analyze and repair (if necessary) damage to the Shuttle's Thermal Protection System.

The size and location of any damage to the Shuttle will be determined during day three of each mission when the orbiter does a Rendezvous Pitch Maneuver in view of the Space Station. Photos taken by astronauts on the Space Station (showing the underside of the orbiter) will be beamed back to Mission Control where the Damage Assessment Team will analyze the damage. A second set of images will be captured on the fourth day of the mission (after docking with the space station), which contain three-dimensional maps of the damage sites.

During the course of a Shuttle mission, the Damage Assessment Team, comprised of engineers from Boeing, NASA Johnson, Ames, and Langley will determine the heating and structural stresses on the orbiter at each damage site.

Computational Fluid Dynamics (CFD) experts from NASA Ames and Langley will be on called upon to analyze the more critical damage sites, and provide a higher level of accuracy to augment the information derived from engineering heating estimates.

Any necessary CFD analyses will be performed in less than 24 hours (during the fourth day of the mission) using multiple dedicated nodes on the Columbia supercomputer, taking about 3,000 processor-hours per damage site. The team will be on stand-by to analyze multiple damage sites during the course of this mission (the team was able to analyze seven sites during the STS-114 mission in July/August 2005). The site-specific re-entry heating environment will be fed into the Boeing Thermal Math Model and Finite Element analysis for determining the fitness of the tile(s) and the airframe for re-entry. Based on their analyses, the team will make recommendations to the Space Shuttle Program chair regarding the damage sites to either leave them "as-is" or repair them before reentry.

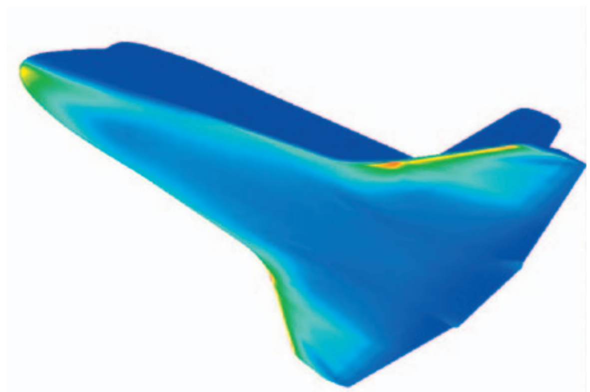


Figure 1: Heating on an undamaged Shuttle during entry into Earth's atmosphere.

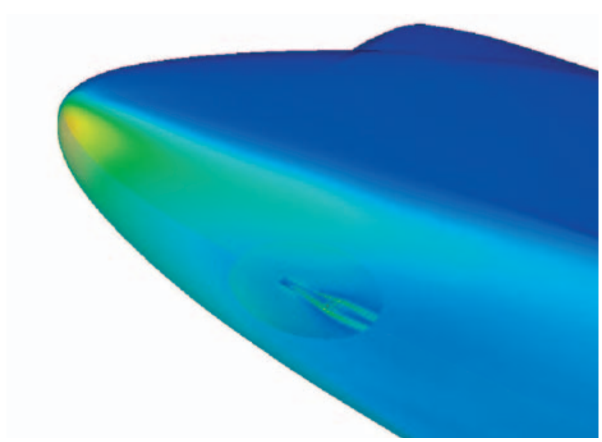


Figure 2: Heating at a damage site as simulated by NASA computational fluid dynamics software on Columbia, the world's fastest operational supercomputer. The color represents heating rate on the surface of the vehicle.

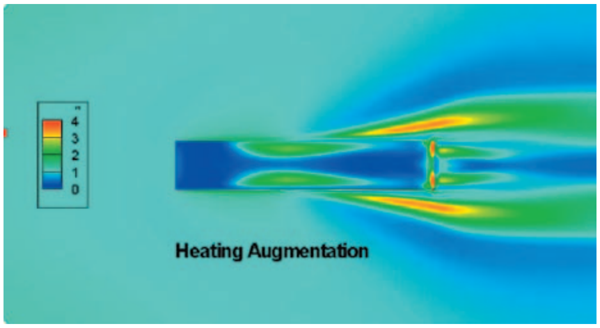


Figure 3: Damage site heating augmentation (relative to undamaged tile heating)

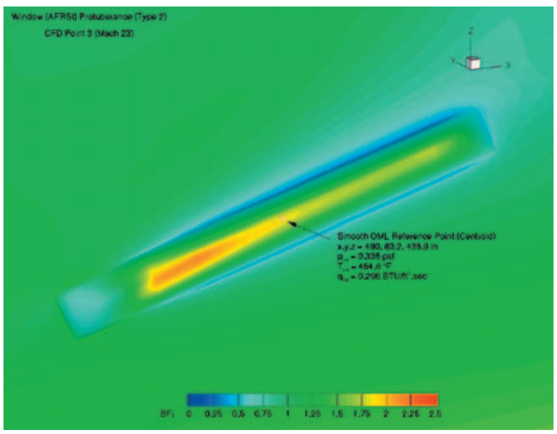


Figure 4: Heating augmentation due to the protruding blanket material near the cockpit window on STS-114.

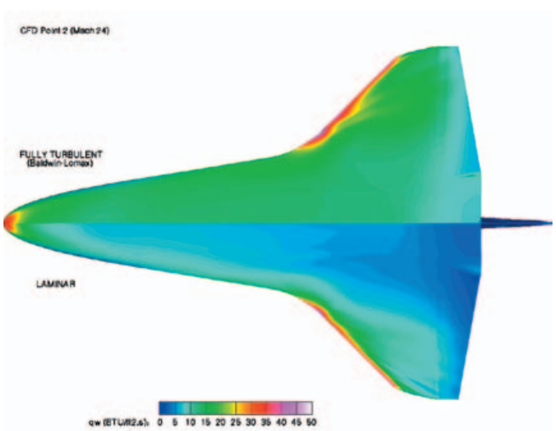


Figure 5: Effects of turbulent heating on orbiter underside and wing leading edge, driving the decision to remove the gap filler on STS-114.

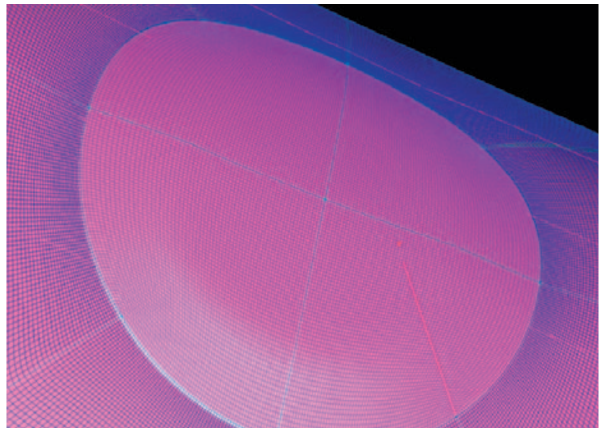


Figure 7: Heating on lip of cover plate.

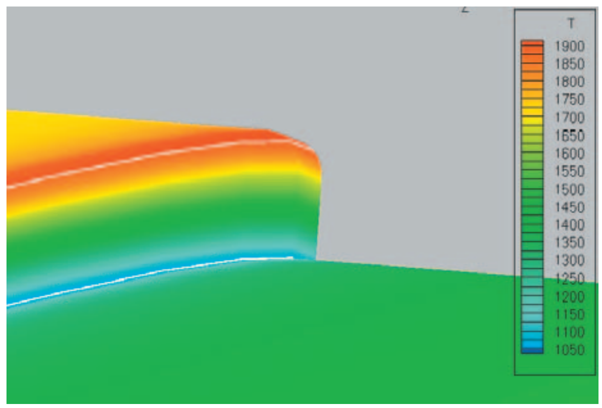


Figure 6: Cover plate (Plug) repair on wing leading edge damage.

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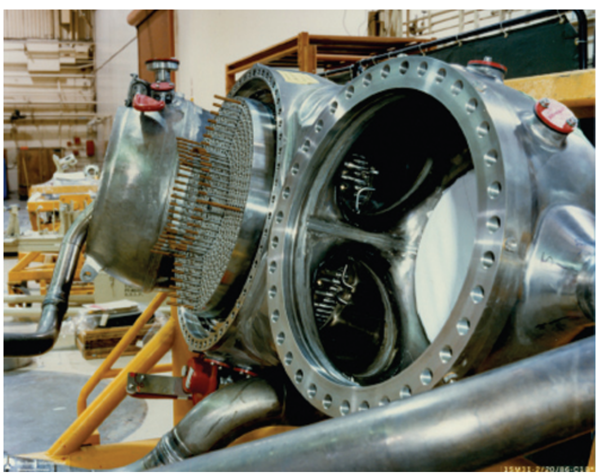
National Aeronautics and Space Administration, NASA Facts:
The Impact of High-End Computing on the Space Shuttle Program

NASAFacts

The Impact of High-End Computing on the Space Shuttle Program Ê

Background

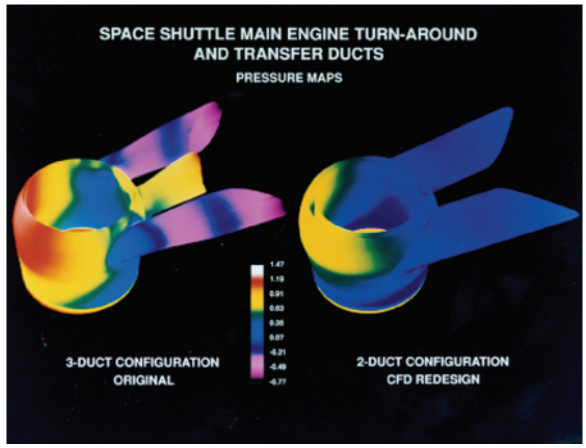
High-end computing and computational fluid dynamics (CFD) have played a key role in improving and enhancing Shuttle performance, reliability, and safety for more than two decades. The NASA Advanced Supercomputing (NAS) Division has been developing CFD-based high-fidelity design and analysis tools, which are being employed to help analyze today's problems, as well as guiding design decisions for future vehicles. The following captures some of the high-level, Shuttle-related events supported by the NAS Division and its supercomputing resources.



Pictured here is the re-designed two-duct hot gas manifold hardware (new powerhead design), which is considered the backbone of the Shuttle engine, and consists of the main injector and two pre-burners, or small combustion chambers, in addition to various propellant and oxidizer pumps, ducts, and lines. (Photo courtesy of Rocketdyne)

Hot Gas Manifold Redesign

The Space Shuttle Main Engine (SSME), designed in the 1970s, is still the most sophisticated reusable rocket engine in the world today. Since its initial design, NASA has continued to increase reliability and safety of Shuttle flight through a series of enhancements, including major design changes to the hot gas manifold and turbopump.



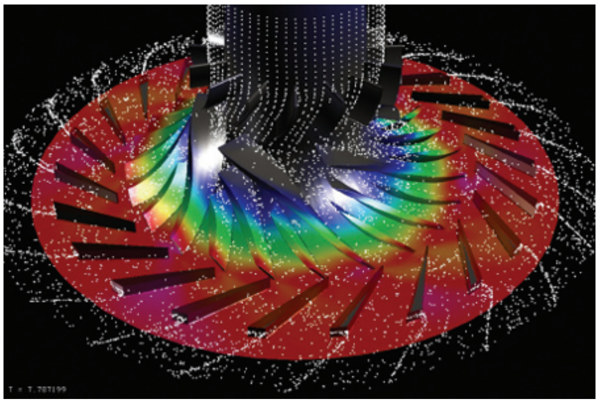
Shown here is a side-by-side comparison of the CFD analyses of the two- and three-duct hot gas manifold designs. White/red represents high pressure, while the blue coloring represents lower pressures. This redesign was the first instance of CFD having an impact in the area of rocket propulsion, and because high-end computing and CFD were so new at the time, code development and analysis were being conducted simultaneously. (Image generated by NASA Ames and Rocketdyne engineers)

The original three-duct hot gas manifold in the powerhead, considered the backbone of the SSME, was replaced by two enlarged ducts. The new two-duct design, facilitated with the use of Cray XMP and Cray 1 supercomputers, and CFD techniques developed by NAS researchers, enhanced overall engine performance and reliability. CFD analyses showed that the two-duct design reduced pressure gradients within the system, and lowered temperatures in the engine during operation, which reduces stress on the turbopump and main injector.

After undergoing extensive testing, the newly designed powerhead made its first flight on Discovery's 20th mission (STS-70) in July 1995, and has been used in all subsequent Shuttle missions.

Advanced Turbopumps and Flowliners

Since 1985, NASA researchers have been working to provide and enhance a computational framework for design and analysis of the entire fuel supply system of a liquid rocket engine (the Space Shuttle Main Engine's liquid oxygen and liquid hydrogen turbopumps, for example),



A snapshot of particle traces and pressure contours resulting from the flow through the Space Shuttle Main Engine's impeller and diffuser. (Image generated by Tim Sandstrom/David Ellsworth, NASA Ames Research Center)

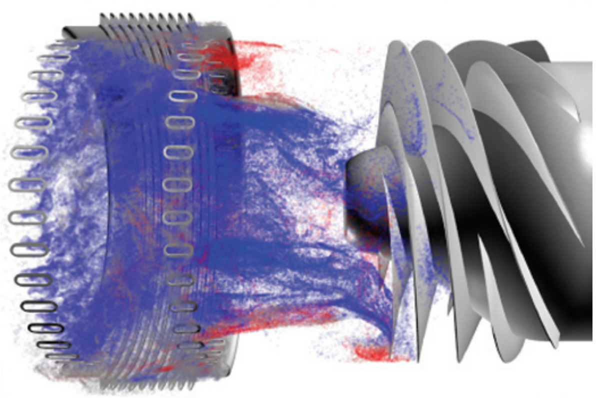


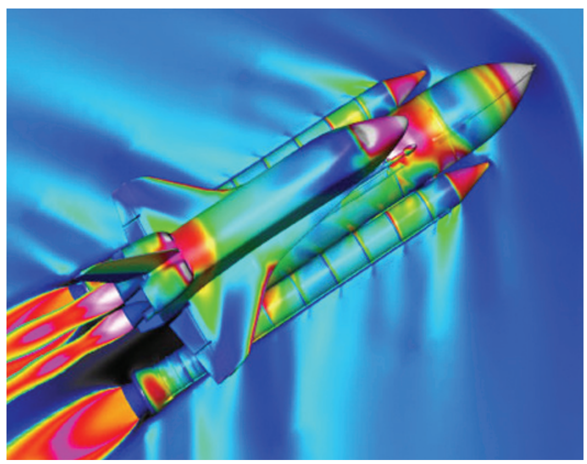
Illustration of unsteady interaction between the backflow and the flow in the bellows cavity—considered one of the major contributors to high-frequency cyclic loading. (Image generated by Tim Sandstrom/David Ellsworth, NASA Ames Research Center)

This effort decreases design costs, improves performance and reliability, and provides developers with information such as transient flow phenomena at startup, impact of non-uniform flows, and impact on the structure. Beginning in 2002, the computational framework was used to investigate the root cause of cracks in the Shuttle engine's fuel-line. In 2004, following the Columbia Shuttle accident, NASA CFD researchers participated in a NASA Engineering and Safety Center-sponsored independent technical assessment investigation of the Shuttle's fuel-line cracks. These results were combined with other analyses and then presented to the Shuttle Program as part of the agency's Return to Flight efforts.

Various computational models have also been developed, and time-accurate computations carried out using this framework to characterize various aspects of the flow field surrounding the flowliner.

Shuttle Ascent Analysis

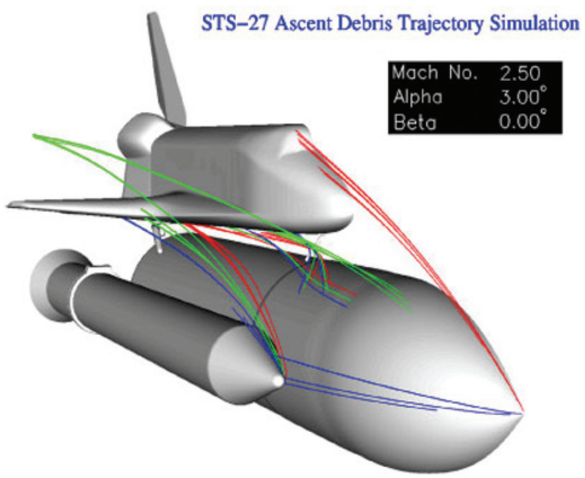
OVERFLOW, a CFD program developed in the early 1990s for solving complex flow problems such as designing launch and reentry vehicles, has been applied to a number of Space Shuttle Launch Vehicle and Space Shuttle Orbiter issues over the past two decades. This CFD application has led to an overall better understanding of the aerodynamic loads on the Space Shuttle, and has served as the primary tool for verifying wind tunnel-derived aerodynamic loads during ascent including Orbiter wing, payload bay door, and vertical tail loads.



This image illustrates the OVERFLOW solution of the Space Shuttle Launch Vehicle flowfield at a Mach number of 1.25. The vehicle surface is colored by the pressure coefficient, and the color contours in the flowfield and plumes represent the local Mach number. (Image generated by Reynaldo Gomez, NASA Johnson Space Center)

Following the Shuttle flight STS-27R during which damage was incurred (launched and landed in December 1988), OVERFLOW was used to perform debris analysis. CFD results, which showed that only isolated potential debris sources existed on the vehicle, led to the determination that insulation and ice were the cause of the damage. This analysis has had a huge positive impact on the Space Shuttle Program, leading to increases in safety of flight by minimizing hazardous debris sources; reducing inspection time; minimizing damage on the next flight; and reducing changes to thermal protection system application procedures.

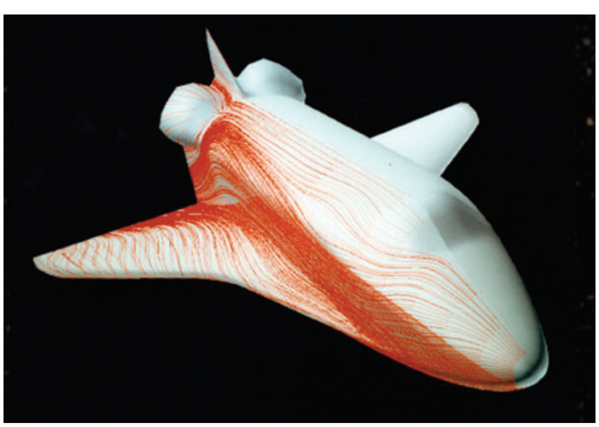
Throughout the 1990s, OVERFLOW was used to support the Shuttle Aerodynamic Loads Verification Program through CFD analysis of the Shuttle Launch Vehicle ascent aerodynamic loads environment. OVERFLOW solutions were used in conjunction with the flight data system, and provided data in areas not covered by flight instruments, yielding a cost savings of approximately $10M.



Example of results obtained during analysis of debris trajectories done during flight STS-27R. Here, the flight conditions are at Mach 2.5 and three degrees angle of attack. (Image generated by Reynaldo Gomez, NASA Johnson Space Center)

Shuttle Reentry Analysis

In 1984, NASA Ames CFD researchers obtained the first ever Navier-Stokes solution on an entire reentry vehicle using a Cray XMP supercomputer. Numerical results for turbulent flow around the complete configuration of the Shuttle Orbiter (including canopy, wing, orbital maneuvering system pods, and vertical tail) at a low supersonic

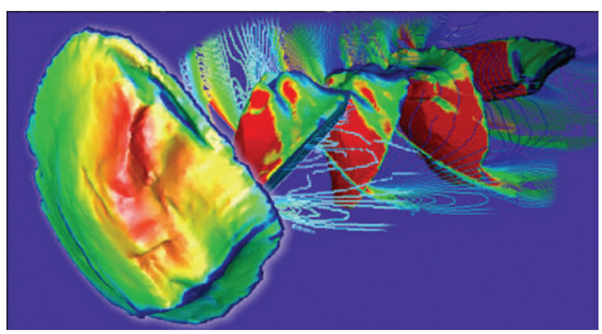


First ever Navier-Stokes solution of the complete configuration of the Shuttle Orbiter. Calculated at Mach 1.4 and zero degrees angle of attack. (Image generated by G. Bancroft and F. Merritt, Applied Computational Fluids Branch, NASA Ames Research Center)

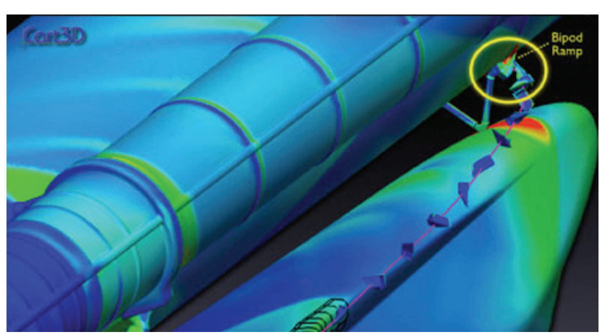
free-stream Mach number of 1.4 and a zero degree angle of attack was obtained by segmenting the flow field into four regions. Segmentation was advantageous in that it maximized the number of gridpoints, thus increasing resolution or detail of the numerical model. These numerical results, which showed good agreement with experimental data, paved the way for the more elaborate CFD analyses conducted following the Shuttle Challenger accident in January 1986.

Columbia (STS-107) Accident Investigation

In response to the Columbia tragedy of February 1, 2003, the NAS Division employed state-of-the-art CFD codes to simulate steady and unsteady flow fields around Columbia during ascent. Simulation results prompted the use of a higher velocity and kinetic energy in foam impact testing done under the Columbia Accident Investigation Board, which showed massive damage to the Orbiter wing reinforced carbon-carbon panels and damaged T-seals due to foam impact. Simulations also provided insight into the mechanism of debris shedding from the bipod-ramp region. Each moving-body simulation required 1,000-5,000 processor hours running on a 1,024-processor SGI Origin supercomputer. Over a very short time period, more than 450 full simulations were run using about 600,000 processor hours.



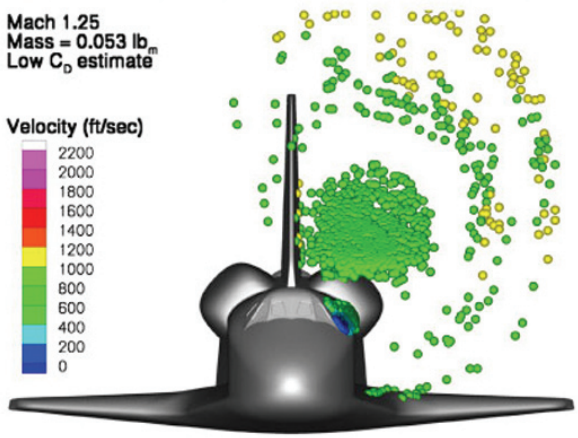
This image shows an unsteady Cart3D simulation used to predict the trajectory of a piece of tumbling foam debris released during ascent. The colors represent surface pressure. (Image generated by Scott Murman, NASA Ames Research Center)



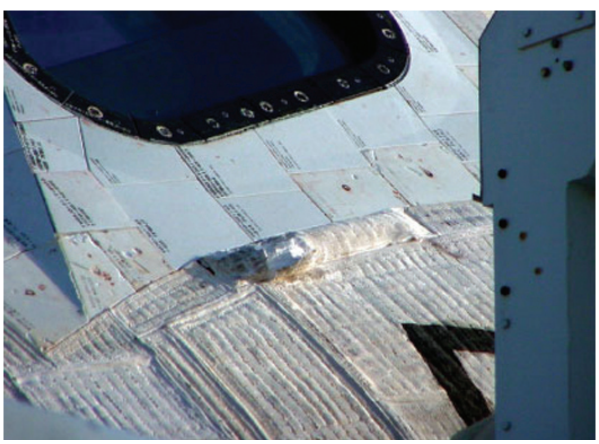
Show here: foam shedding from the bipod ramp region and its path to impact reinforced carbon-carbon panels on the Orbiter wing. (Image generated by Michael Aftosmis, NASA Ames Research Center)

Discovery (STS-114) Mission Support

During the Discovery mission (summer 2005), NAS Division researchers were on stand-by to provide debris transport analysis support using the NASA Ames-developed debris-transport software running on the 10,240-processor SGI Altix supercomputer, Columbia. Several incidences throughout the mission required NAS resources:



An example of the CFD-based debris-transport analysis conducted on the torn Advanced Flexible Reusable Surface Insulation blanket, showing probable impact locations for debris of a certain size at a certain flight condition (velocity). Results from CFD analyses were used to establish flow conditions (for example, Mach number and angle-of-attack) for wind tunnel tests conducted to gather more extensive information about the torn blanket. (Image generated by Reynaldo Gomez, NASA Johnson Space Center)



Post-flight photo of the torn 20 x 3 inch panel of the Advanced Flexible Reusable Surface Insulation blanket located under the commander's window on the Discovery Shuttle. (Image courtesy of NASA Orbiter Ops and Project Mgmt Office)

- Evaluation of the potential threat from ice forming on one of the solid rocket boosters/ external tank (SRB/ET) aft attach struts on launch day. The ice was a resultant of liquid nitrogen leaking from the ground umbilical connector plate on the ET. Debris simulations were run on Columbia and reported to NASA Johnson within 90 minutes. The threat never materialized, as the final ice inspection from NASA Kennedy reported that no ice was present on this strut.

- Analyses of ice/frost ramp foam debris that were shed 155 seconds into the mission. Within several hours from being tasked by NASA Johnson to analyze the threat of a potential hit on the starboard wing of the Orbiter, NAS researchers delivered an analysis of a complete set of debris simulations indicating that this debris would not cause damage. This conclusion was reinforced by a detailed examination of the on-orbit inspection results, which showed that this debris did not cause any damage to Orbiter tiles or reinforced carbon-carbon panels.

- Analyses of a torn 20 x 3 inch panel of the Advanced Flexible Reusable Surface Insulation blanket located under the commander's window on the Discovery Orbiter using both the debris-transport analysis software and wind tunnel tests. Results indicated that fraying and incremental erosion was the primary failure mode, and large debris fragments were unlikely (which would have resulted in another extravehicular activity).

The Columbia supercomputer is a 10,240-processor SGI Altix system with a 51.9 trillion-per-second processing capability. Columbia is currently the agency's main supercomputing resource for NASA missions.

National Aeronautics and Space Administration

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National Aeronautics and Space Administration, NASA Facts:
NASA Ames Ascent Debris Transport Analysis

NASA Ames Ascent Debris Transport Analysis Ê

Background

In 2003, the Columbia Accident Investigation Board determined that foam debris striking the wing leading-edge upon ascent was directly responsible for the loss of the Space Shuttle Columbia and its seven crew members on February 1, 2003.

As part of its Return to Flight (RTF) efforts, NASA has instituted a comprehensive study of the threat posed by debris to future launches, in order to minimize or eliminate this risk. The debris analysis team is a critical component of the RTF effort. This team uses simulation-based modeling and experimental results to quantify the damage potential of known debris sources on the launch vehicle.

The team is comprised of members of several NASA centers who are utilizing Ames Research Center's supercomputers, wind-tunnels, and ballistic range to study the aerodynamics of a wide range of debris shapes, sizes, and materials. These results are being used to develop engineering tools to accurately simulate the debris environment during ascent, which is critical to determining that the vehicle is safe to fly. These debris analysis tools will also be used for in-flight analysis of debris sighted during the vehicle's ascent trajectory.

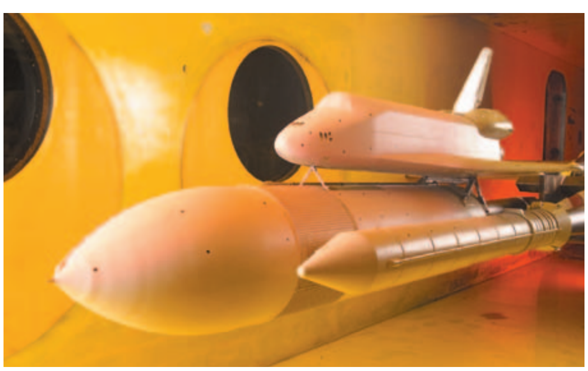

Figure 1: Photo of the 3 percent wind-tunnel model of the Space Shuttle in the NASA Ames Unitary Wind Tunnel.

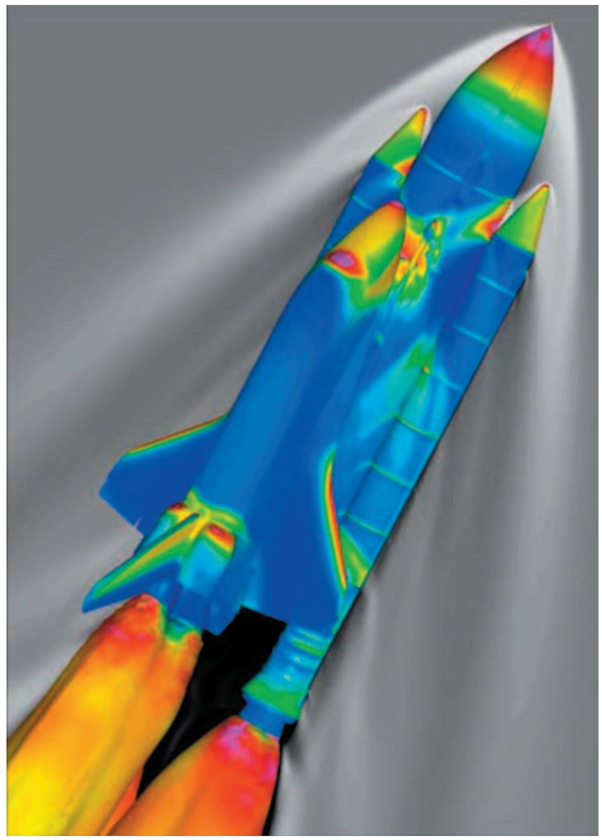

Figure 2: Flowfield around the Space Shuttle Launch Vehicle traveling at Mach 2.5 during ascent, as simulated by NASA computational fluid dynamics software on Columbia, the world's fastest operational supercomputer.

The color represents the pressure coefficient on the surface of the vehicle, and the gray contours represent the air density.

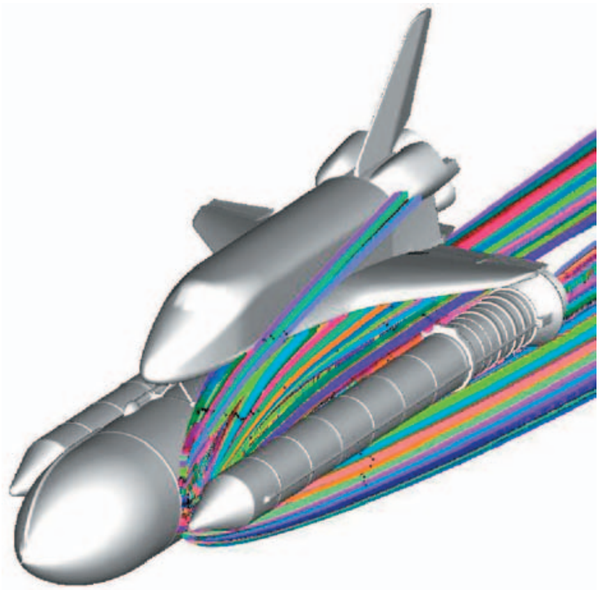

Figure 3: Plot of several trajectories depicting the path of debris shed from the External Tank.

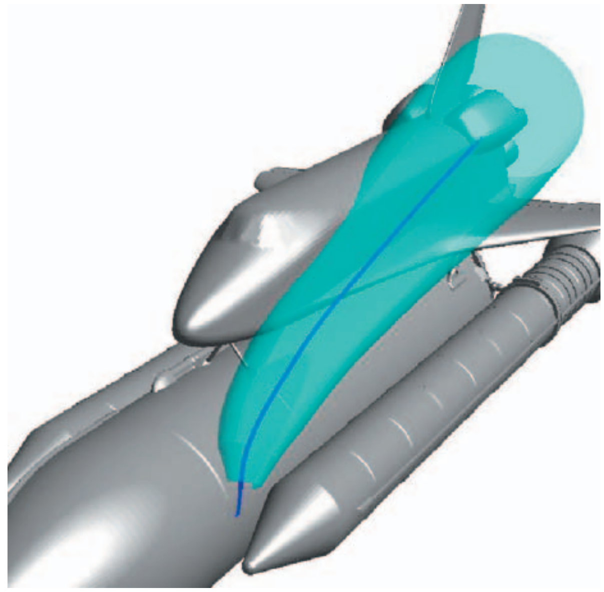

Figure 4: Debris cone used to predict all possible impact locations from a single debris piece.

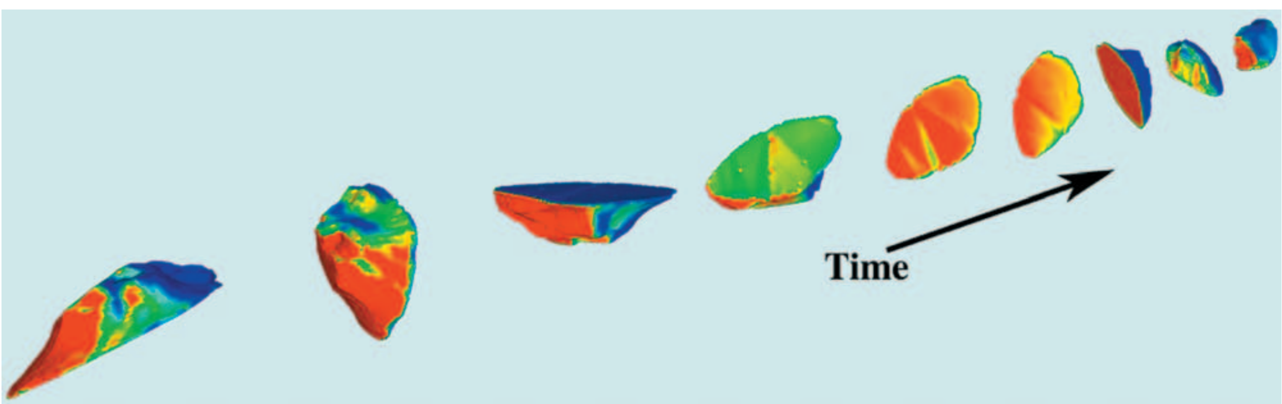

Figure 5: Time sequence of a computed six degree-of-freedom trajectory of an actual foam divot from the External Tank.

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Additional Images:

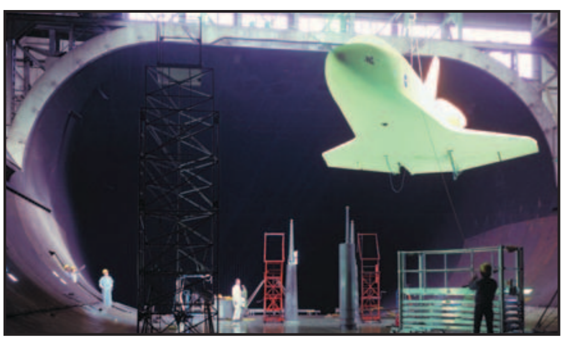
36% Scale Orbiter Model

36% Scale Orbiter Model (A-100) in 40-By 80-Foot Wind Tunnel, 30 June 1975 (Source: NASA Ames Research Center, AC75-1141-3.1)

36% Scale Orbiter Model in 40-By 80-Foor Wind Tunnel, 27 February 1976 (Source: NASA Ames Research Center, AC76-0430-4)

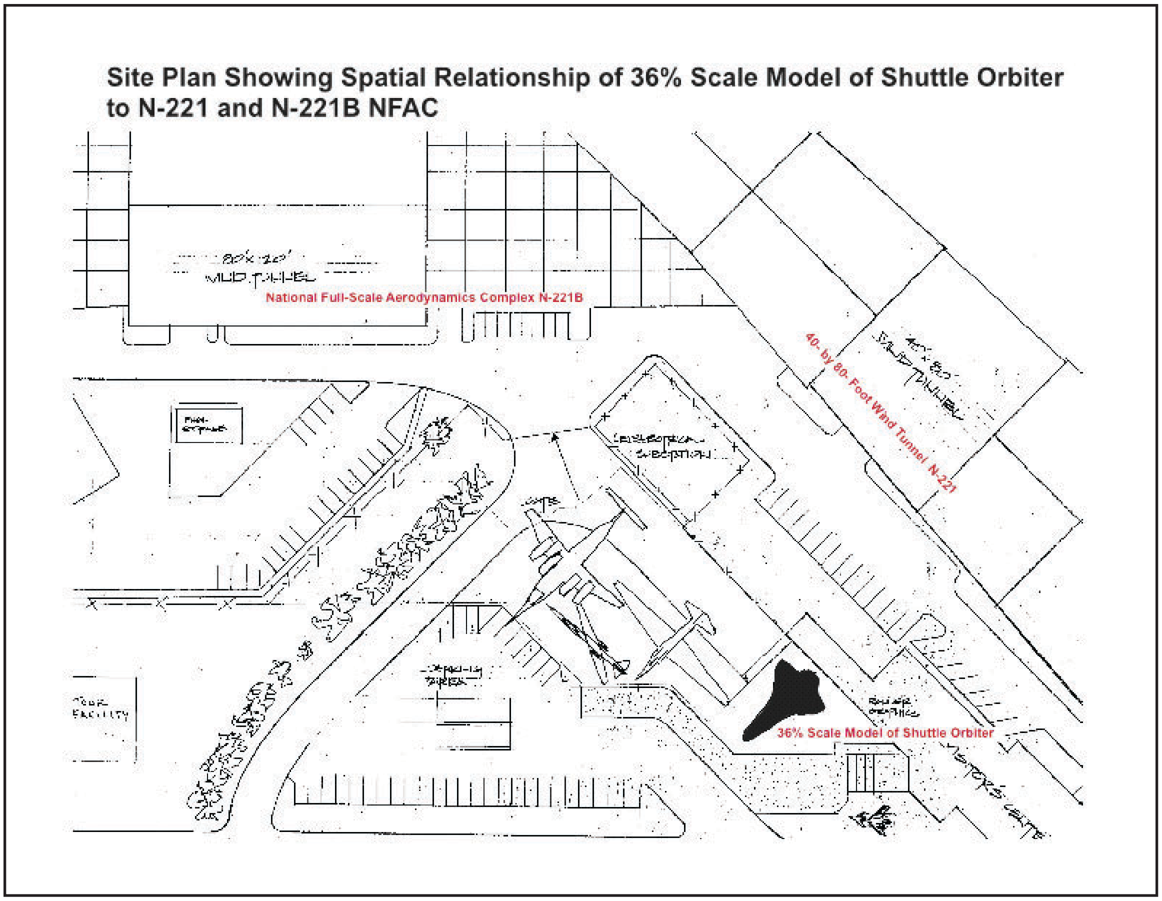
36% Scale Orbiter Model Installation in 40-By 80-Foot Wind Tunnel, 1 December 1975 (Source: NASA Ames Research Center, AC75-2584)

Space Shuttle Orbiter 101 mated to modified Boeing 747 (NASA-905) aircraft for in-flight transport tests, 18 February 1977 (Source: NASA Ames Research Center, 108-KSC-77PC-92)



36% Scale Orbiter Model, Space Shuttle Orbiter 101 Model Installation in 40-By 80-Foot Wind Tunnel, 1 December 1975 (Source: NASA Ames Research Center, AC75-2582)

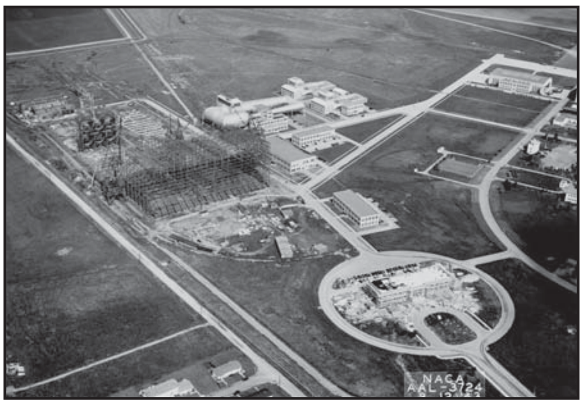
36% Scale Orbiter Model Display at former Ames Visitor Center (N-233), 13 February 1990 (Source: NASA Ames Research Center, AC90-0086-16)



Site Plan showing Spatial Relationship of 36% Scale Orbiter Model to N-221 and N-221B (NFAC)
(Source: Roger Ashbaugh, Cultural Resources Manager, Ames Environmental Services Division, "Evaluation of Historic Resources Associated with the Space Shuttle Program at Ames Research Center, Supplemental Information on Selected Properties," 8 February 2007)

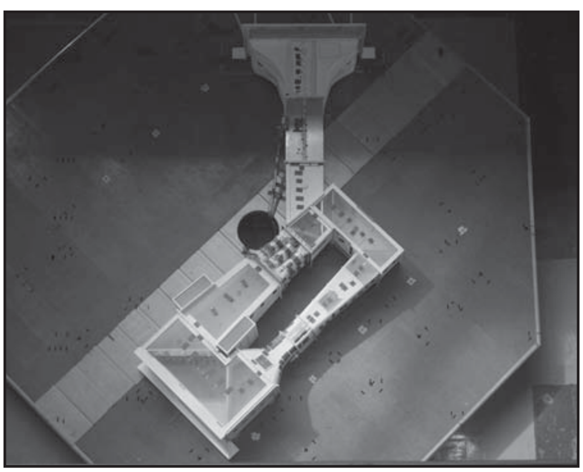
Additional Images:

N-221: 40-By 80-Foot Wind Tunnel



N-221, Construction of 40-By 80-Foot Wind Tunnel, 12 March 1943
(Source: NASA Ames Research Center, AAL-3724)

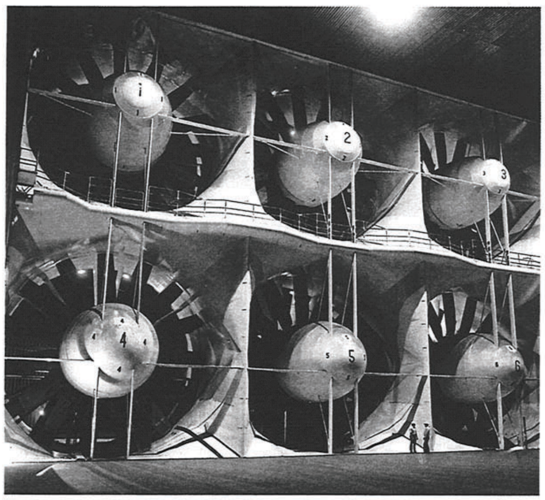
N-221, interior of the 40-By 80-Foot Wind Tunnel Test Section
(Source: NASA Ames Research Center, AC94-0071-257)



N-221, 1/50th Scale NFAC Modification Model
(Source: NASA Ames Research Center, A76-0635)

Test Section	40- by 80-Foot	80- by 120-Foot
Max Speed	350 mph	115 mph

Max power: 135,000 hp, 105 MW
Six drive motors
Fan diameter: 40 ft
15 blades per fan
Fan rpm: 36 to 180
Blade angle: -5° to 52°
Maximum airflow: 63 tons/sec



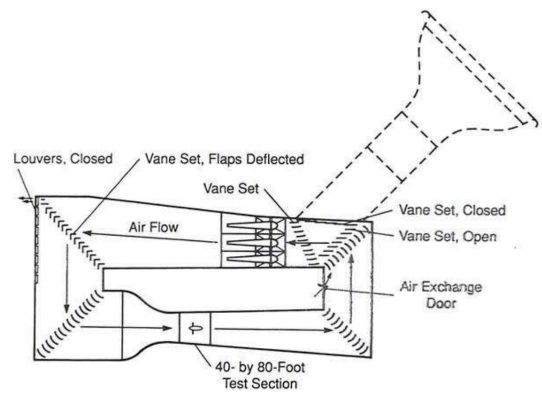
NFAC Drive Fans

NFAC Research

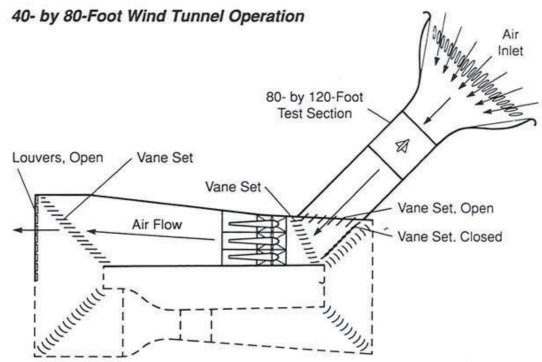
Takeoff and landing, low-speed, cruise
- Conventional aircraft
- V/STOL aircraft
- Rotorcraft

Aeroacoustics

Propulsion integration



40- by 80-Foot Wind Tunnel Operation



80- by 120-Foot Wind Tunnel Operation

NASA
National Aeronautics and
Space Administration

Ames Research Center
Moffett Field, California 94035

N-221, Diagram of the 40-By 80 Foot Wind Tunnel and the 80-By 120 Foot Wind Tunnel
(Source: NASA Ames Research Center phamplet)

Architectural Drawings for N-221

40-Foot x 80-Foot Wind Tunnel Storage & Electric Equipment Rooms, Elevations
Architect: National Advisory Committee for Aeronautics
Date: 18 April 1941
Sheet: D-269
NASA EDC # 221-4101-A3

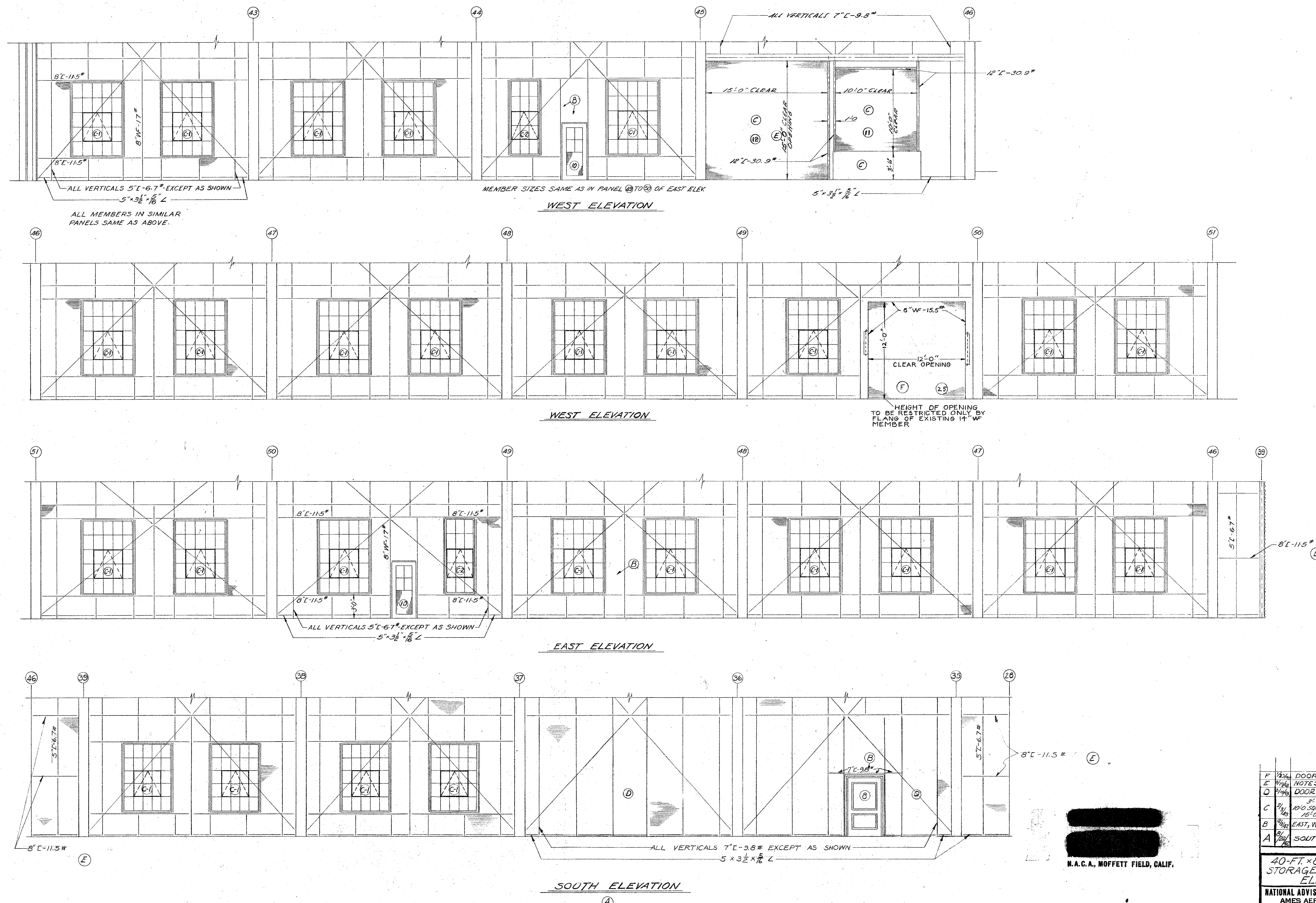
40-Foot x 80-Foot Wind Tunnel Offices & Storage Rooms, Elevations
Architect: National Advisory Committee for Aeronautics
Date: 9 September 1942
Sheet: D-268
NASA EDC # 221-4201-A1

40-Foot x 80-Foot Wind Tunnel Miscellaneous Storage, West Elevation
Architect: National Advisory Committee for Aeronautics
Date: 1 January 1945
Sheet: AD-3014E
NASA EDC # 221-4404-A1

40 x 80 Foot Wind Tunnel, Floor Plans
Architect: Pietras
Date: 11 February 1986
Sheet: 1
NASA EDC # 221-8450-A1

40 x 80 Foot Wind Tunnel, First Floor Plan
Architect: Pietras
Date: 11 February 1986
Sheet: 2
NASA EDC # 221-8450-A2

40 x 80 Foot Wind Tunnel, First Floor Plan
Architect: Pietras
Date: 11 October 1986
Sheet: 1
NASA EDC # 221-8450-A3



[redacted]

N.A.C.A., MOFFETT FIELD, CALIF.

F	1/23/45	DOOR ADDED IN WEST ELEV.	O.R
E	3/19/43	NOTES DELETED, 15'-0" WAS 14'-1"	E.S.
D	3/10/43	DOORS DELETED, SOUTH ELEV.	E.S.
C	2/3/43	3'-6" PLATFORM ADDED, 10'-0 SQ. ROLLING DOOR RELOCATED, 15'-0" ROLLING DOOR ADDED.	E.D.M.
B	12/3/42	EAST, WEST & SOUTH ELEV. REVISED.	K.S.B.
A	8/22/42	SOUTH ELEVATION ADDED	R.S.H.

REVISIONS

40-FT. × 80-FT. WIND TUNNEL
STORAGE & ELECT. EQUIP. ROOMS
ELEVATIONS

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS
AMES AERONAUTICAL LABORATORY
MOFFETT FIELD, CALIFORNIA

SCALE 3/16" = 1'-0"

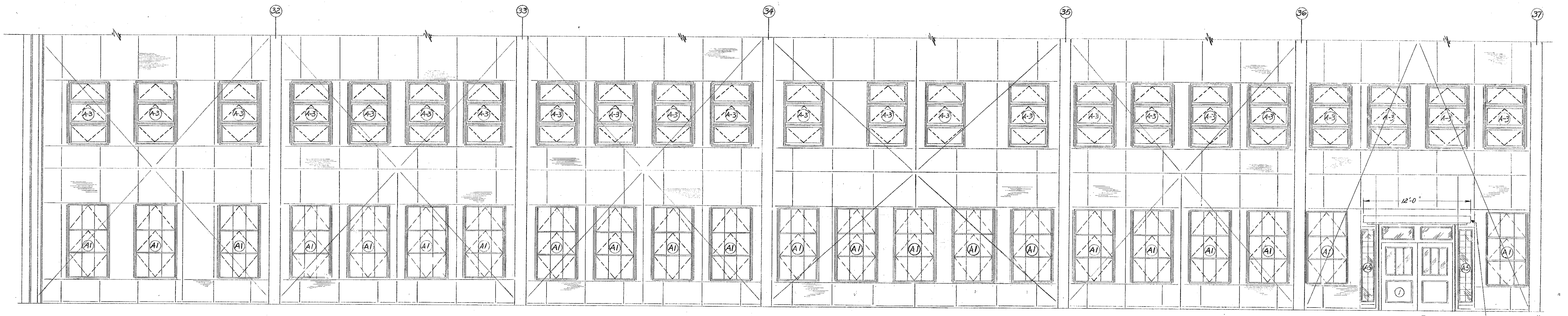
DR. WINSTEIN	4-9-41
CH.	4-18-41
APP.	4-18-41
APP.	4-18-41

D-269F

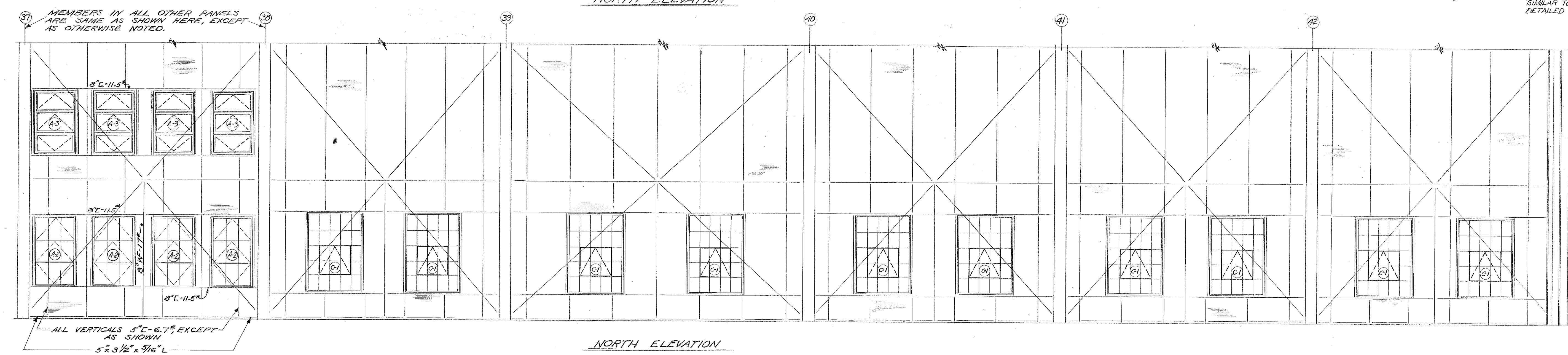
D-269

221 H101A 1130H2

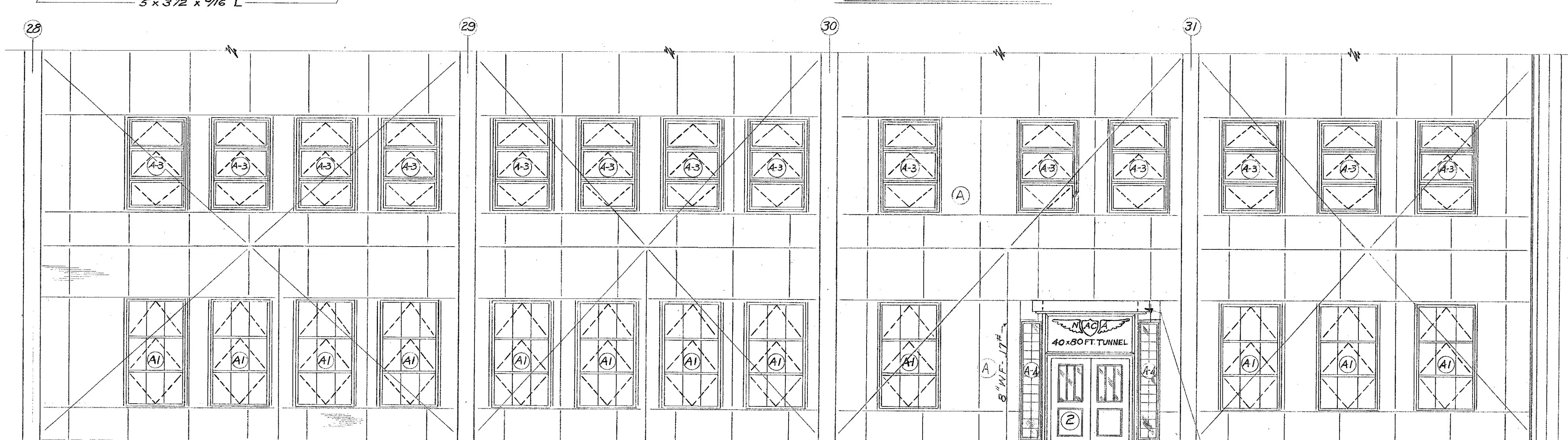
166



NORTH ELEVATION



NORTH ELEVATION



EAST ELEVATION

SEE D-270 FOR CANOPY & INSIGNIA

NOTE:
THIS DRAWING SUPERSEDES D-268

A	3/5/43	EAST ELEV. - 8WF-17# WAS 8"WF-27#, DIAG. DELETED NORTH ELEV. CORRECTED	GEB

REVISIONS

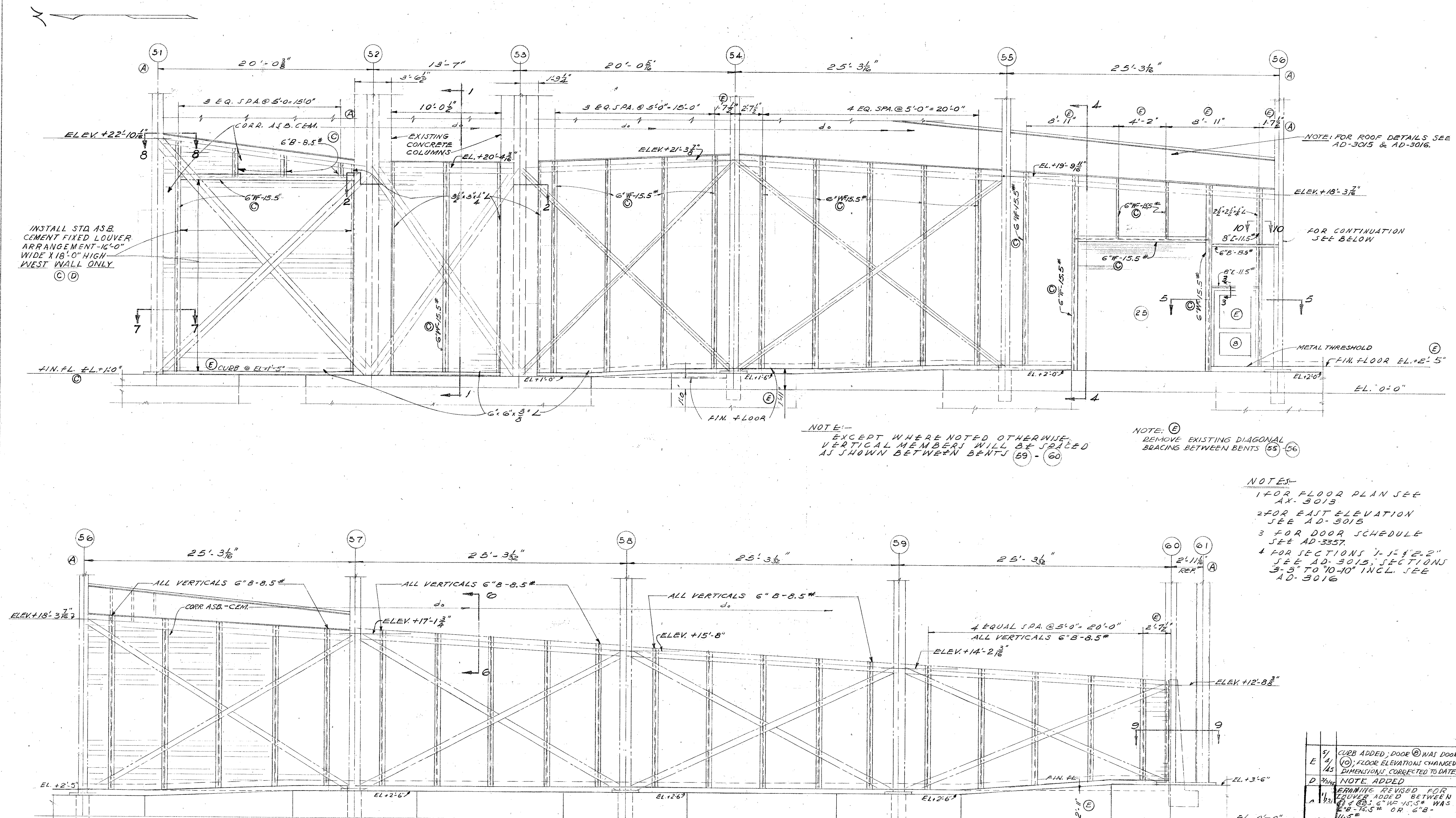
40-FT. x 80-FT. WIND TUNNEL
OFFICES & STORAGE ROOMS
ELEVATIONS

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS
AMES AERONAUTICAL LABORATORY
L.E.P. MOFFETT FIELD, CALIFORNIA

DR.	R. HUGHES	8-21-42
CH.	E.S.	9-9-42
APP.	[illegible]	9-9-42
APP.		

SCALE 3/16" = 1'-0"

AD-1081 221 4201 A 1 PH-5



NOTE:- EXCEPT WHERE NOTED OTHERWISE, VERTICAL MEMBERS WILL BE SPACED AS SHOWN BETWEEN BENTS (59) - (60)

NOTE: (E) REMOVE EXISTING DIAGONAL BRACING BETWEEN BENTS (55)-(56)

NOTES-
1 FOR FLOOR PLAN SEE AX-3013
2 FOR EAST ELEVATION SEE AD-3015
3 FOR DOOR SCHEDULE SEE AD-3357.
4 FOR SECTIONS 1-1" & 2-2" SEE AD-3015, SECTIONS 3-3" TO 10-10" INCL. SEE AD-3016

WEST ELEVATION

E	5/4/45	CURB ADDED; DOOR (8) WAS DOOR (10); FLOOR ELEVATIONS CHANGED; DIMENSIONS CORRECTED TO DATE.	WEF
D	3/5/45	NOTE ADDED	PS
C	1/23/45	FRAMING REVISED FOR LOUVER ADDED BETWEEN (51) & (52); 6"WF-15.5" WAS 6"B-15.5# OR 6"B-11.5#	PBM
B	9/10/44	REVISED TO DATE	RRB
A	7/29/44	DIMENSIONS CORRECTED TO SHOW SLOPE OF WALL	EJM

REVISIONS

40 FT. x 80 FT. WIND TUNNEL
MISCELLANEOUS STORAGE
WEST ELEVATION

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS
AMES AERONAUTICAL LABORATORY
MOFFETT FIELD, CALIFORNIA

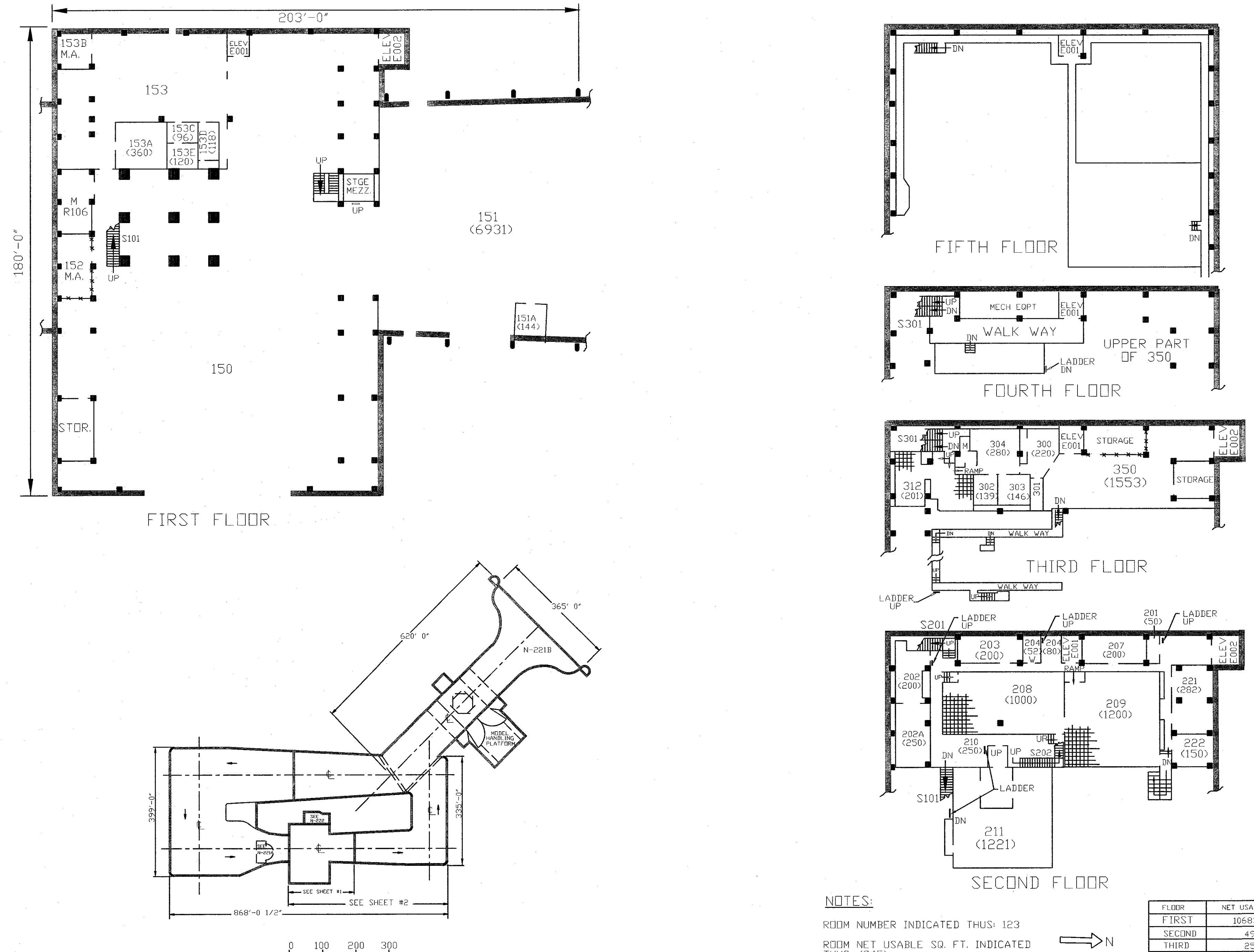
SCALE 1/4" = 1'-0"

AD-3014E

AD-3014

DWG NO. A221-8450-A1 | SH. 1 | REV. F

NOTES:



NOTES:

ROOM NUMBER INDICATED THUS: 123

ROOM NET USABLE SQ. FT. INDICATED THUS: (345)

N

FLOOR	NET USABLE SQ. FEET
FIRST	106837
SECOND	4967
THIRD	2539
TOTAL	114343

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION AMES RESEARCH CENTER MOFFETT FIELD, CALIFORNIA	SCALE, FT. 10 0 10 20 30 40 50	DWG NO. A221-8450-A1	REV F	DATE 8/91	GROSS BLDG SQ FT 150906	TITLE 40 X 80 X 120 FOOT WIND TUNNEL	BLDG NO. N-221

SHEET 1 OF 4

ZONE	LETTER	DESCRIPTION	DRAWN	DATE	APPROVAL
	F	UPDATED PER ECO A34205	VAK	8-91	
	E	REVISED PER ECO # 23276	DR	12/89	
	D	REVISED PER ECO 13251	JLO	12-85	
	C	DWG # WAS A221-7701-A1	JLO	6/84	
	B	DWG # WAS A13180-C221-1	JLO	6/84	
	A	REVISED TO DATE	ML	10-79	

REVISIONS

DRAWN: R. STIVERS	DATE 10-17-78
DESIGNER:	DATE
CHECKED:	DATE
PROJ. MGR:	DATE
REQUESTER:	DATE
R & QA:	DATE
SAFETY:	DATE
SUPERVISOR:	DATE

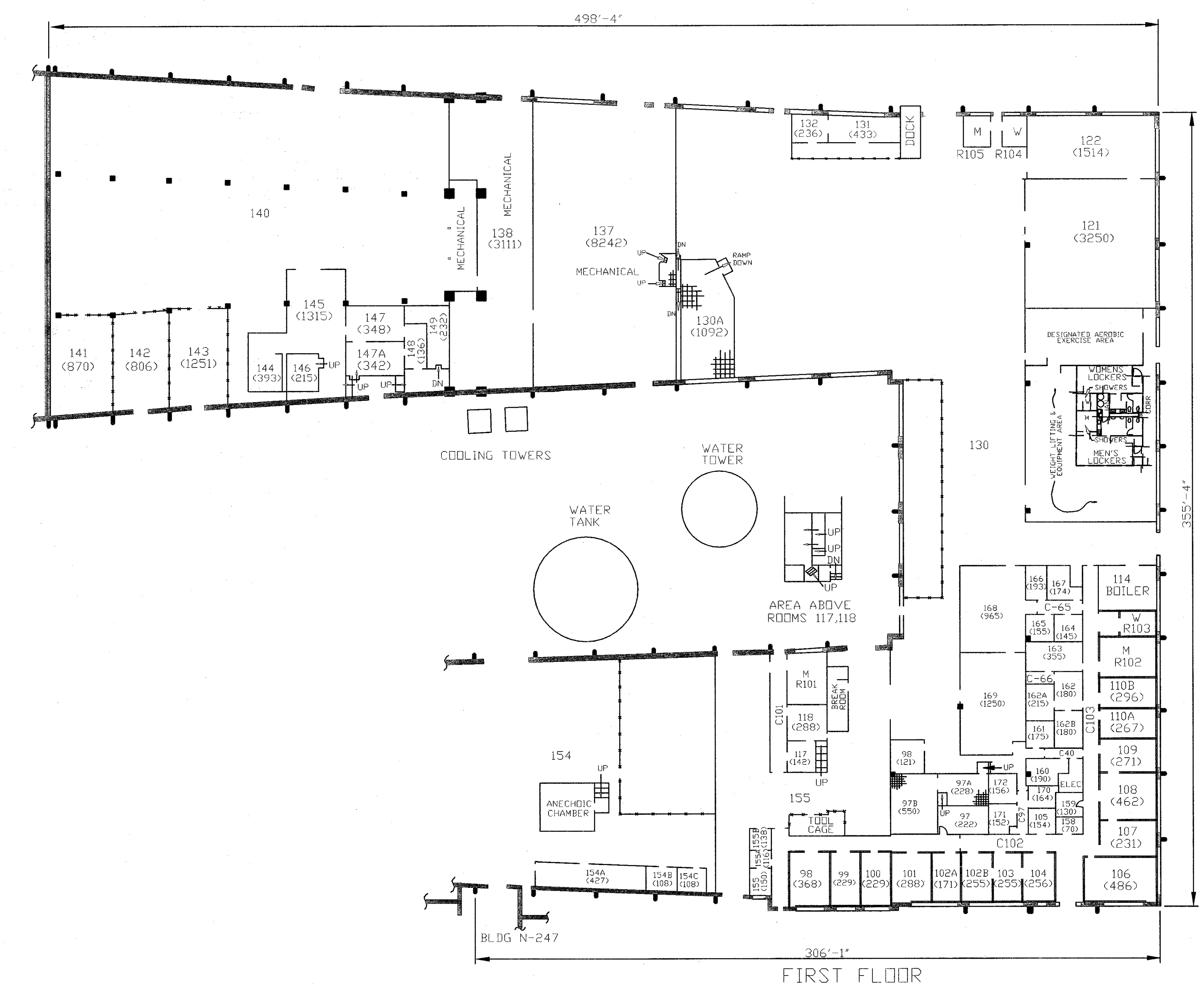
NASA Ames Research Center
Moffett Field, California 94035

40 X 80 FT WIND TUNNEL
FLOOR PLAN
BLDG N-221

SIZE	CAGE CODE		REV.
D	25307	A 221-8450-A1	F
SCALE: 1/24" = 1'	INDEX DATE: 2/11/86	SHEET 1 OF 4	

FILENAME: A221A1(ACAD/11)

NOTES:



FLOOR	NET USABLE SQ. FEET
FIRST	106837
SECOND	4967
THIRD	2539
TOTAL	114343

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION AMES RESEARCH CENTER MOFFETT FIELD, CALIFORNIA	SCALE, FT.	DWG NO	REV	DATE	GROSS BLDG SQ FT	TITLE	BLDG. NO.
	10 0 10 20 30 40 50 60	A221-8450-A2	F	8/91	150,906	40 X 80 FOOT WIND TUNNEL	N-221

SHEET 2 OF 4

ZONE	LETTER	DESCRIPTION	DRAWN	DATE	APPROVAL
	F	UPDATED PER ECO A34205	VAK	8-91	
	E	REVISED PER ECO A23276	VAK	10-88	
	D	REVISED PER ECO 13251	JLO	12-85	
	C	ADDED ROOMS 160 THRU 165 DWG NO. WAS A221-7701-A2	RAD	6-84	
	B	REVISED TO DATE	ML	10-79	
	A	REDRAWN ON APPLICON FROM DWG. NO. A13180-C221-2	RCS	9-78	

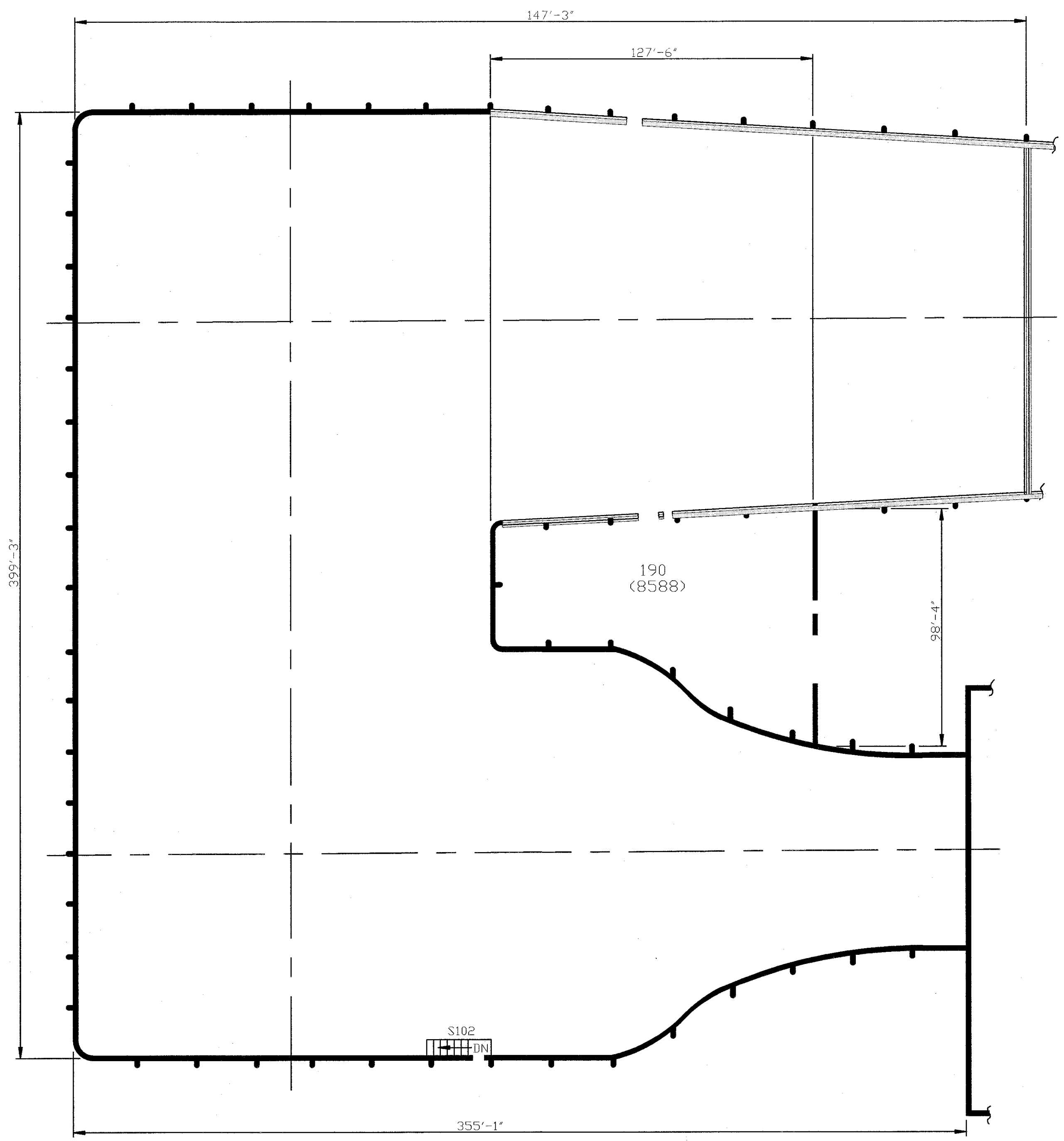
REVISIONS

DRAWN: R. STIVERS	DATE 10-26-78	NASA Ames Research Center Moffett Field, California 94035
DESIGNER: PIETRAS	DATE	
CHECKED:	DATE	40 X 80 FT WIND TUNNEL FLOOR PLAN BLDG N-221
PROJ. MGR:	DATE	
REQUESTER:	DATE	
R & QA:	DATE	
SAFETY:	DATE	
SUPERVISOR:	DATE	SIZE D · CAGE CODE 25307 · A221-8450-A2 · REV. F

SCALE: 1/32" = 1' · INDEX DATE: · SHEET 2 OF 4

FILENAME: A221A2(ACAD/11)

DWG NO. A221-8450-A2 SH. 2 REV. F



FIRST FLOOR

NOTES:

ROOM NUMBER INDICATED THUS: 123

ROOM NET USABLE SQ. FT. INDICATED THUS: (345)

FLOOR	NET USABLE SQ. FEET
FIRST	8588

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION AMES RESEARCH CENTER MOFFETT FIELD, CALIFORNIA	SCALE, FT. 10 0 10 20 30 40 50 60 70	DWG NO.	REV	DATE	GROSS BLDG SQ FT	TITLE	BLDG. NO.
		A221-8450-A3	E	12/89	150906	40 X 80 FOOT WIND TUNNEL SHEET 3 OF 4	N-221

LETTER	DATE	REVISION DESCRIPTION	DRAWN	APP.
E	12-89	REVISED PER ECO 23276	DR	
D	12-85	REVISED PER ECO 13251	JLO	
C	6/84	DWG.# WAS A221-7701-A3	JLO	
B	6/84	DWG.# WAS A13180-C221-3	JLO	
A	10-79	REVISED TO DATE	ML	

NASA **Ames Research Center** Moffett Field, California

40 X 80 FT WIND TUNNEL
FLOOR PLAN, SH.3
BLDG N-221

DRAWN R. STIVERS	CHECKED	INDEX 2-11-86	MATERIAL	LIMITS UNLESS NOTED
DESIGN ENGINEER PIETRAS	BRANCH		REDRAWN 10-11-78	FRAC DEC. ANG.
APPROVED	ASSM.DWG.NO.			
APPROVED AP 12-20-85	SCALE 1/32" = 1'		A 221-8450-A3 E	

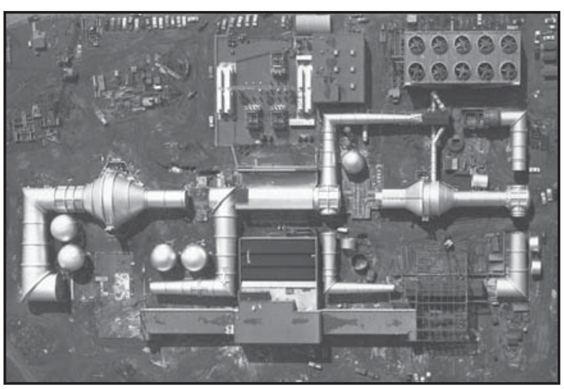
A221A3(ACAD/11)

Additional Images:

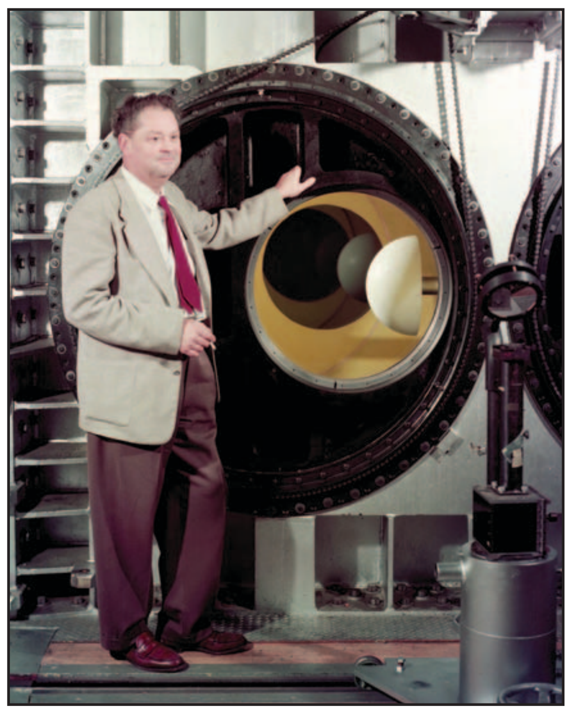
N-227A to D: Unitary Plan Wind Tunnels

N-227, north facade, center bay
(Source: Page & Turnbull)

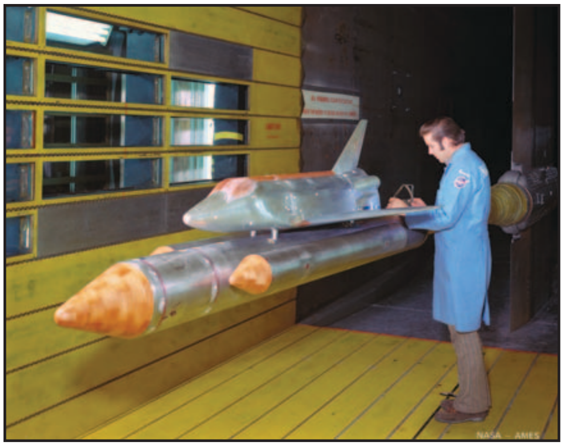
N-227, interior of 11-By 11-Foot Wind Tunnel
(Source: Page & Turnbull)



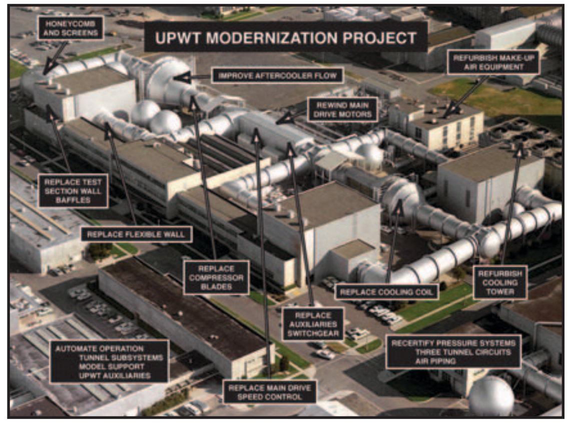
N-227, Construction progress on 8-Foot Supersonic Wind Tunnel, 25 March 1954
(Source: NASA Ames Research Center, A-8ft-SSWT-162)



N-227, H. Julian Allen in 8-By 7-Foot Test Section of Unitary Plan Wind Tunnel
(Source: NASA Ames Research Center, A-23438)

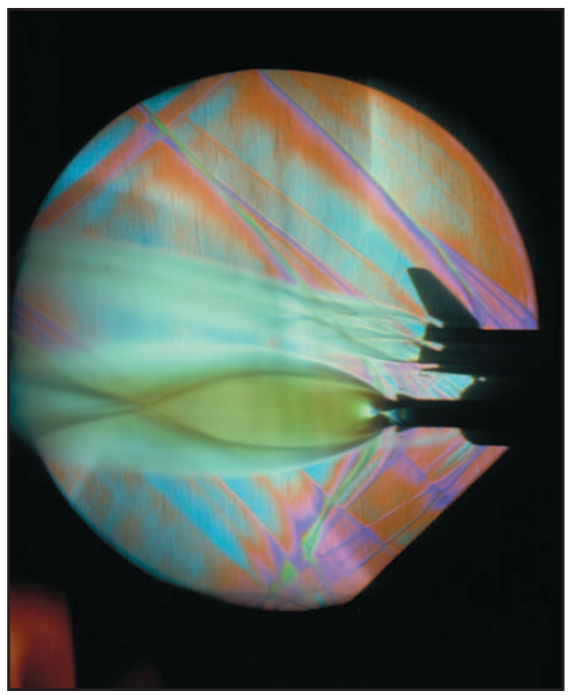


N-227, MSC 040A Space Shuttle: 11-By 11-Foot Wind Tunnel Tests, 27 January 1972 (Source: NASA Ames Research Center, AC72-1344)

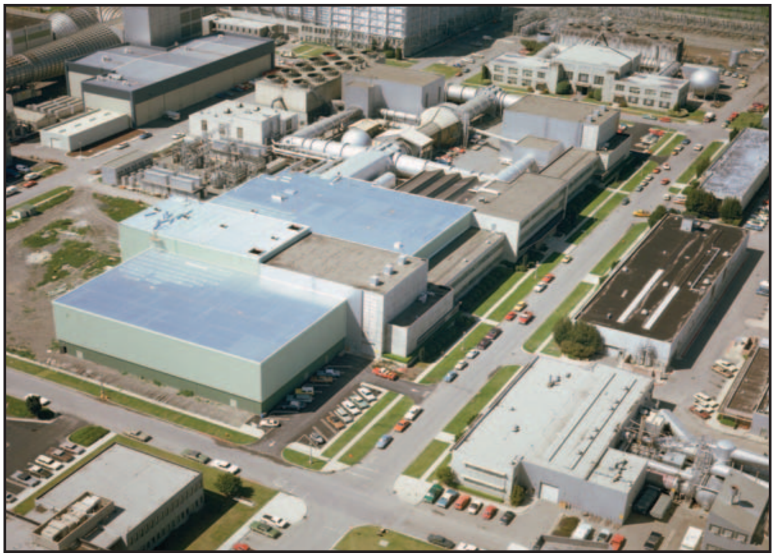


N-227, Aerial survey of Unitary Plan Wind Tunnel and High Speed Aerodynamics Facilities, 6 February 1967 (Source: NASA Ames Research Center, A-8ft-SSWT-162)

N-227, Space Shuttle (SSV) IA-105 Model, 9-By 7-Foot Wind Tunnel Test 242-2-97, 27 January 1978 (Source: NASA Ames Research Center, AC78-0082-3)

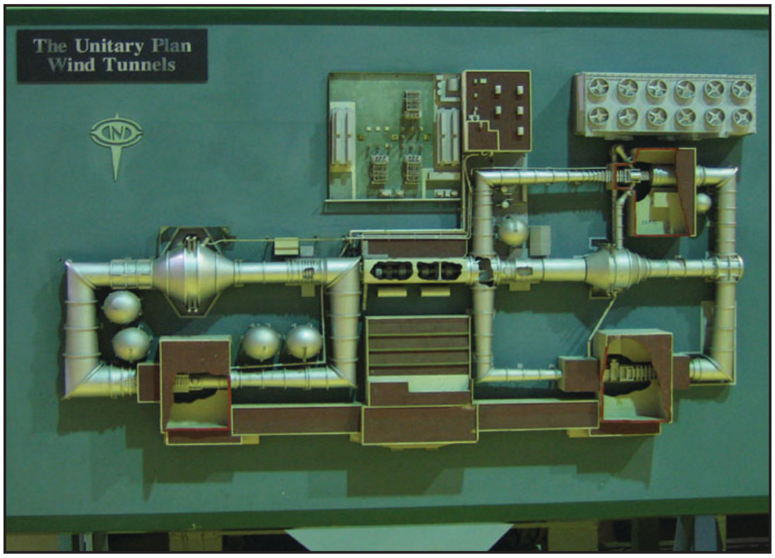


N-227, Space Shuttle Plume Test 97-044-1 in 9-By 7-Foot Wind Tunnel, 4 January 1975 (Source: NASA Ames Research Center, AC75-0207)

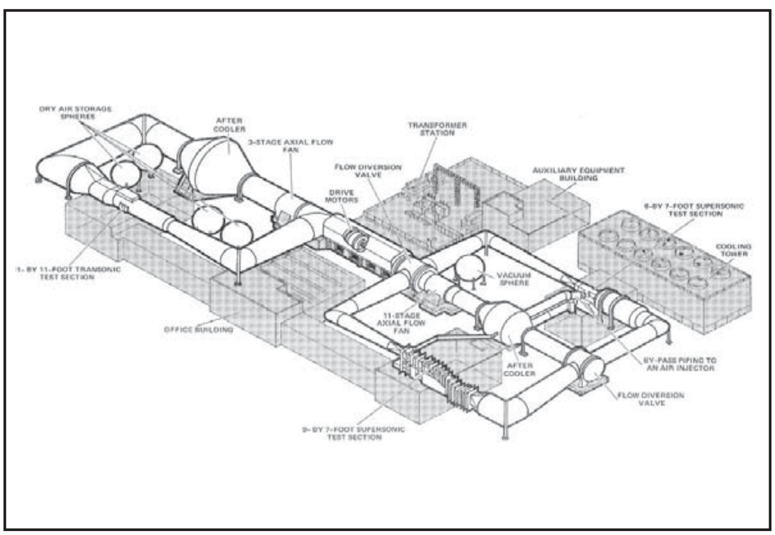


N-227, Unitary Plan Wind Tunnels, 11 April 1974
(Source: NASA Ames Research Center, AC74-1400)

N-227, Unitary Plan Wind Tunnels, 1 August 1990
(Source: NASA Ames Research Center, AC90-0466-21)



N-227, Model of Unitary Plan Wind Tunnels, August 2006
(Source: Page & Turnbull)



N-227, Diagram of Unitary Plan Wind Tunnels
(Source: *NASA Ames Facilities Summary*, 1974)

Architectural Drawings for N-227A to D

8 Foot Supersonic Wind Tunnel Auxiliaries Building, Elevations
Architect: Bechtel Corporation
Date: N/A
Sheet: A 9718-X4
NASA EDC # 227-5101-A4

Central & Test Chamber Buildings, 8 Ft. Supersonic Wind Tunnel, First and Second Floor Plans
Architect: John A. Blume
Date: 31 October 1952
Sheet: A9720-A1
NASA EDC # 227-5104-A1

Central & Test Chamber Buildings, 8 Ft. Supersonic Wind Tunnel, Third Floor and Roof
Architect: John A. Blume
Date: 31 October 1952
Sheet: A9720-A2
NASA EDC # 227-5104-A2

Central & Test Chamber Buildings, 8 Ft. Supersonic Wind Tunnel, First Floor Plan, East Wing and Test Chamber I
Architect: John A. Blume
Date: 31 October 1952
Sheet: A9720-A4
NASA EDC # 227-5104-A4

Central & Test Chamber Buildings, 8 Ft. Supersonic Wind Tunnel, First and Second Floor Plans
Architect: John A. Blume
Date: 31 October 1952
Sheet: A9720-A10
NASA EDC # 227-5104-A10

Central & Test Chamber Buildings, 8 Ft. Supersonic Wind Tunnel, Key Plans
Architect: John A. Blume
Date: 31 October 1952
Sheet: A9720-A11
NASA EDC # 227-5104-A11

Central & Test Chamber Buildings, 8 Ft. Supersonic Wind Tunnel, Elevations (Front and Rear), East Wing and Test Chamber I
Architect: John A. Blume
Date: 31 October 1952
Sheet: A9720-A12

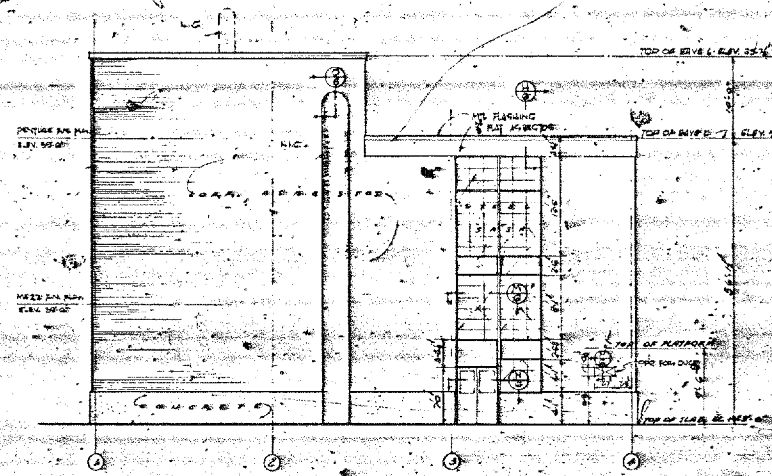
NASA EDC # 227-5104-A12

Central & Test Chamber Buildings, 8 Ft. Supersonic Wind Tunnel, Elevations (Side), East Wing and Test Chamber I, West Wing and Test Chamber II
Architect: John A. Blume
Date: 31 October 1952
Sheet: A9720-A13
NASA EDC # 227-5104-A13

Central & Test Chamber Buildings, 8 Ft. Supersonic Wind Tunnel, Elevations (Front and Rear), West Wing and Test Chamber II
Architect: John A. Blume
Date: 31 October 1952
Sheet: A9720-A14
NASA EDC # 227-5104-A14

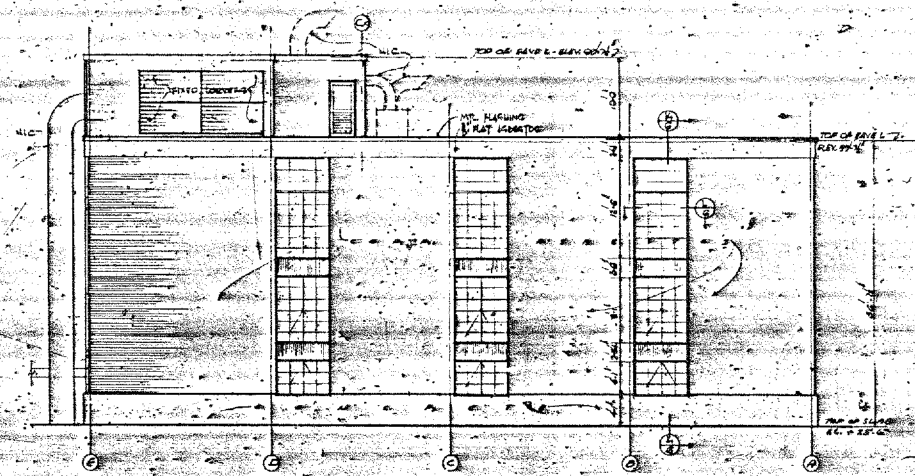
Central & Test Chamber Buildings, 8 Ft. Supersonic Wind Tunnel, Elevations, Center Unit, Typical Wing Section
Architect: John A. Blume
Date: 31 October 1952
Sheet: A9720-A15
NASA EDC # 227-5104-A15

Unitary Plan Wind Tunnel Building, First and Second Floor Plans
Architect: National Aeronautics and Space Administration, Ames Research Center Moffett Field, CA
Date: August 1991
Sheet: 227-8450-A1
NASA EDC # 227-8450-A1



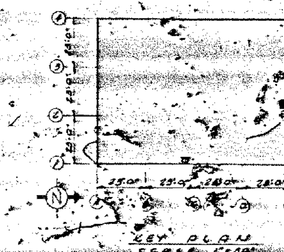
NORTH ELEVATION

SCALE 1/8" = 1'-0"

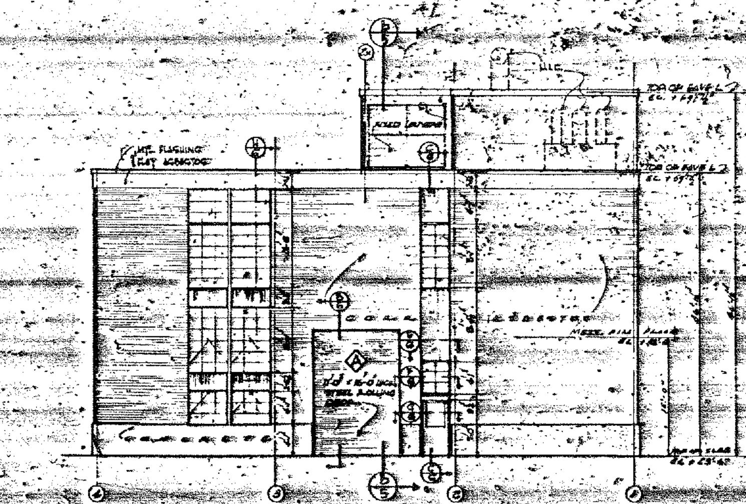


WEST ELEVATION

SCALE 1/8" = 1'-0"

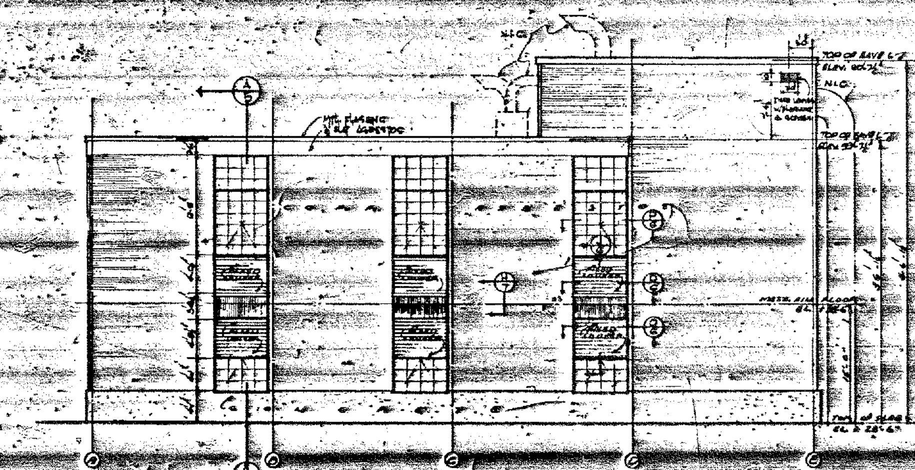


KEY PLAN



SOUTH ELEVATION

SCALE 1/8" = 1'-0"



EAST ELEVATION

SCALE 1/8" = 1'-0"

LET	DATE	REVISIONS	CH'K	APP.

BECHTEL CORPORATION
SAN FRANCISCO, CALIFORNIA

JOB NO. 1758

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS
AMES AERONAUTICAL LABORATORY
MOFFETT FIELD, CALIF.

6 FT. SUPERSONIC WIND TUNNEL
AUXILIARIES BUILDING
ELEVATIONS

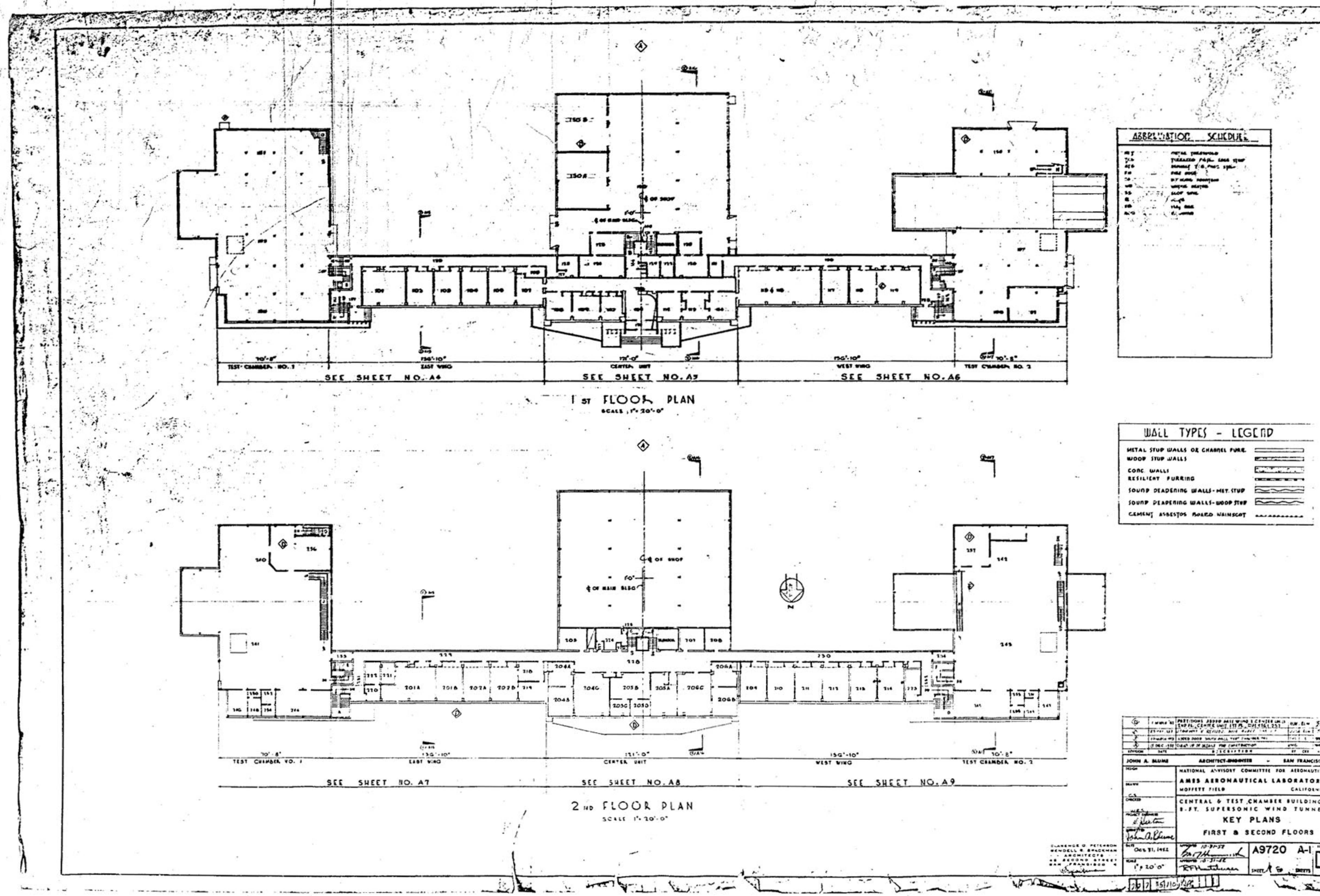
MATERIAL
HEAT TREAT
PROTECT FINISH
NO. REQ'D PER ASS'Y
ASS'Y DWG. NOS.
LIMITS ON DIMENSIONS UNLESS OTHERWISE NOTED
FRACTIONAL ±
DECIMAL ±
ANGULAR ±

DESIGN
DRAWN BY
CHECKED BY
SECTION
DIVISION

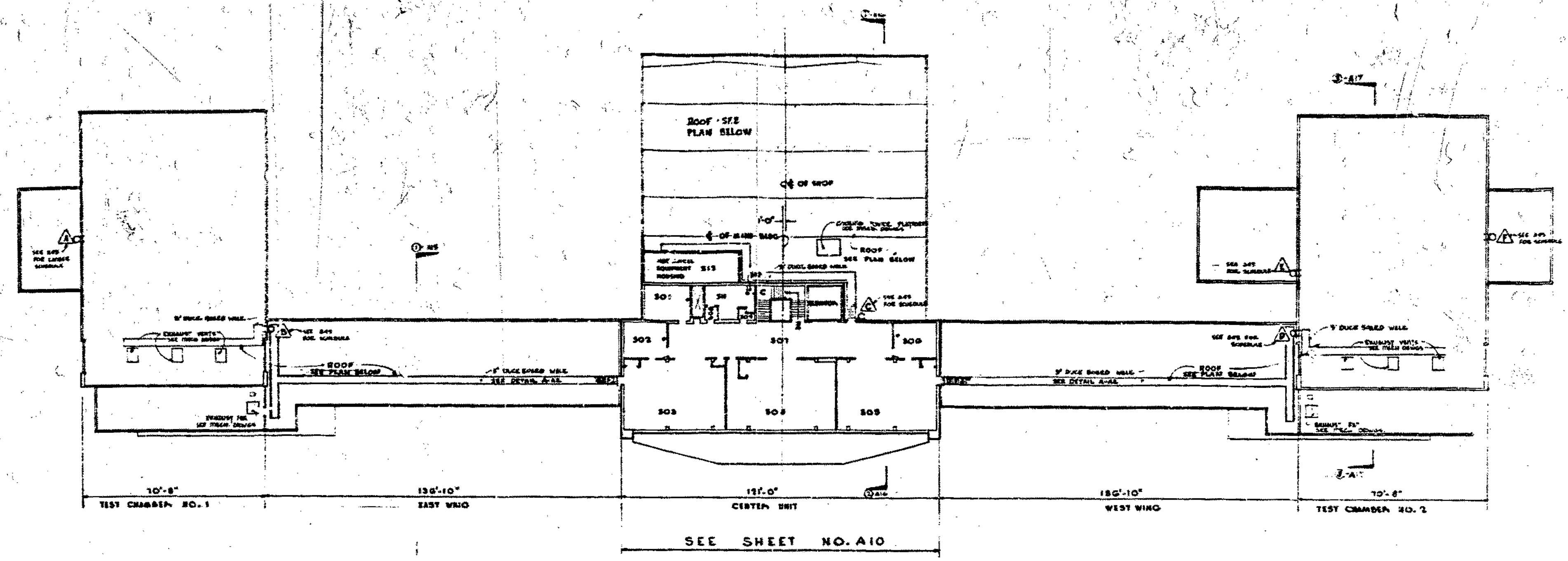
A-9718-X4 A

SHEET

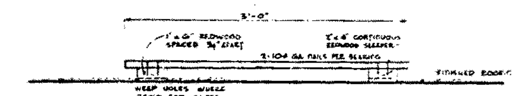
227 5401 114



ABBREVIATION SCHEDULE
70'-8"
TEST CHAMBER NO. 1
136'-10"
EAST WING
131'-0"
CENTER UNIT
150'-10"
WEST WING
70'-8"
TEST CHAMBER NO. 2
SEE SHEET NO. A4
SEE SHEET NO. A5
SEE SHEET NO. A6
1ST FLOOR PLAN
SCALE 1" = 20'-0"
WALL TYPES - LEGEND
METAL STUD WALLS OR CHANNEL FURR.
WOOD STUD WALLS
CONC. WALLS
RESILIENT FURRING
SOUND DEADENING WALLS - MET. STUD
SOUND DEADENING WALLS - WOOD STUD
CEMENT ASBESTOS BOARD WAINSCOT
70'-8"
TEST CHAMBER NO. 1
136'-10"
EAST WING
131'-0"
CENTER UNIT
150'-10"
WEST WING
70'-8"
TEST CHAMBER NO. 2
SEE SHEET NO. A7
SEE SHEET NO. A8
SEE SHEET NO. A9
2ND FLOOR PLAN
SCALE 1" = 20'-0"
REVISION
DATE
DESCRIPTION
JOHN A. BLUME
ARCHITECT-ENGINEER
SAN FRANCISCO
NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS
AMES AERONAUTICAL LABORATORY
MOFFETT FIELD
CALIFORNIA
CENTRAL & TEST CHAMBER BUILDINGS
8-FT. SUPERSONIC WIND TUNNEL
KEY PLANS
FIRST & SECOND FLOORS
DATE Oct. 31, 1952
SCALE 1" = 20'-0"
A9720
A-1
D



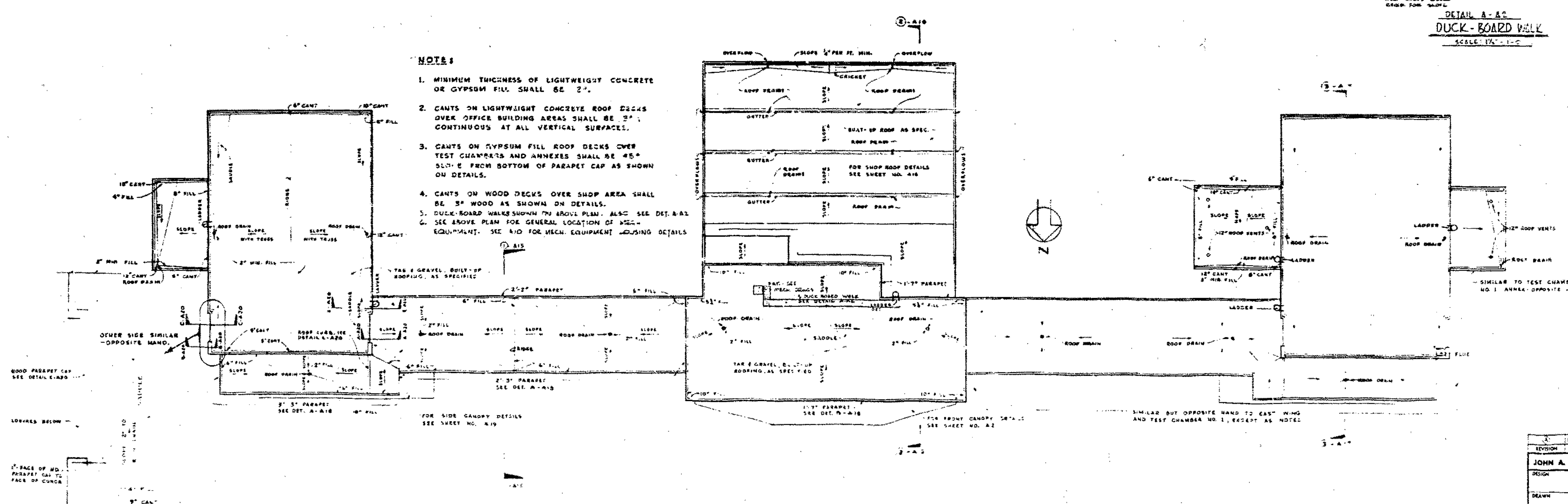
3rd FLOOR PLAN (A)
SCALE 1" = 20'-0"



DETAIL A-A2
DUCK-BOARD WALK

NOTES:

1. MINIMUM THICKNESS OF LIGHTWEIGHT CONCRETE OR GYPSUM FILL SHALL BE 2".
2. CANTS ON LIGHTWEIGHT CONCRETE ROOF DECKS OVER OFFICE BUILDING AREAS SHALL BE 3", CONTINUOUS AT ALL VERTICAL SURFACES.
3. CANTS ON GYPSUM FILL ROOF DECKS OVER TEST CHAMBERS AND ANNEXES SHALL BE 45° SLOPE FROM BOTTOM OF PARAPET CAP AS SHOWN ON DETAILS.
4. CANTS ON WOOD DECKS OVER SHOP AREA SHALL BE 3" WOOD AS SHOWN ON DETAILS.
5. DUCK-BOARD WALKS SHOWN ON ABOVE PLAN. ALSO SEE DET. A-A2
6. SEE ABOVE PLAN FOR GENERAL LOCATION OF MECH. EQUIPMENT. SEE A10 FOR MECH. EQUIPMENT HOUSING DETAILS



ROOF PLAN
SCALE 1" = 20'-0"

REVISION	DATE	DESCRIPTION	BY	CKD	APP
A	15 DEC. 1952	CLEAN UP OF DETAILS FOR CONSTRUCTION			

JOHN A. BLUME — ARCHITECT-ENGINEER — SAN FRANCISCO

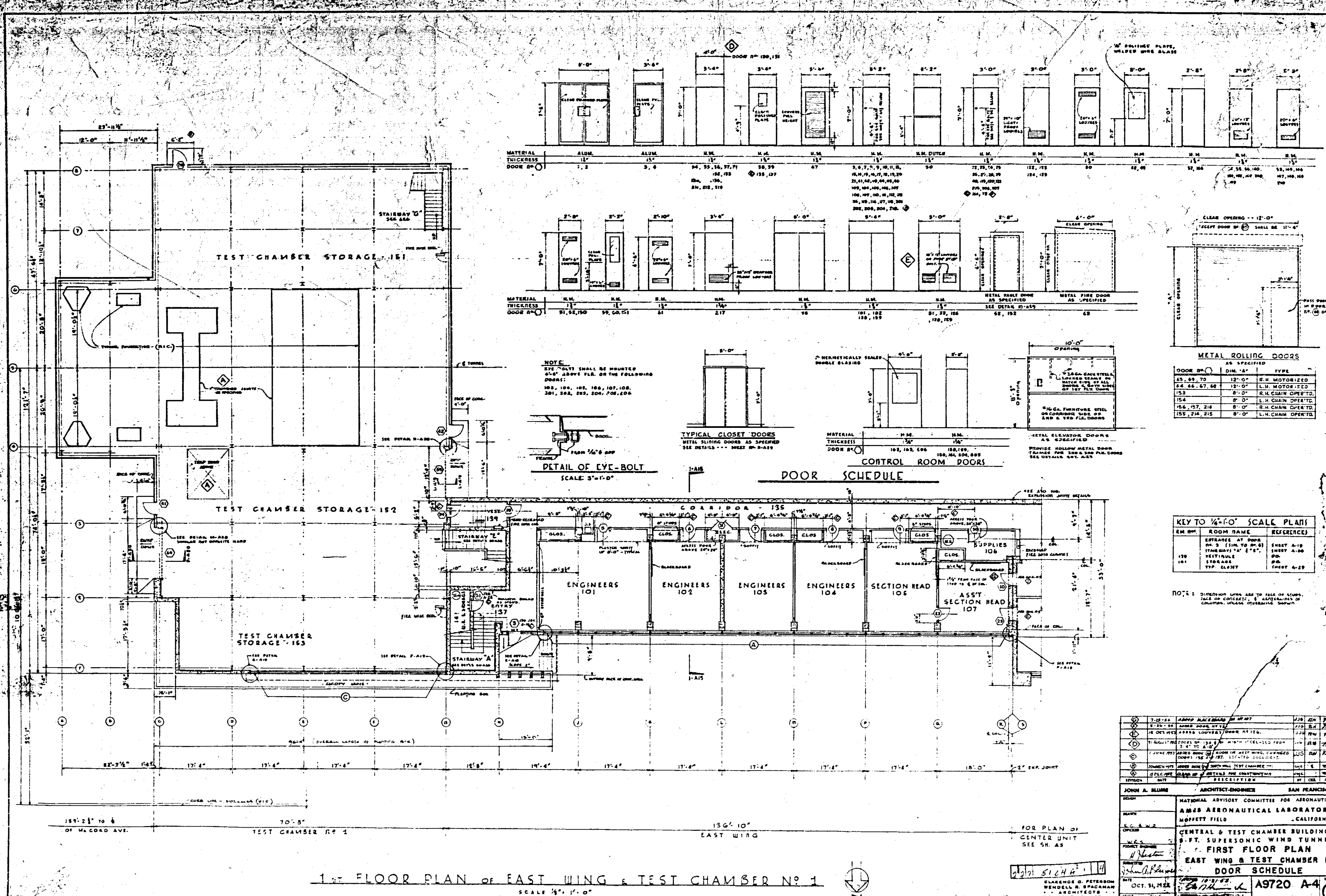
CLARENCE D. PETERSON
WENDELL R. SPACKMAN
ARCHITECTS
48 SECOND STREET
SAN FRANCISCO

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS
AMES AERONAUTICAL LABORATORY
MOFFETT FIELD, CALIFORNIA

CENTRAL & TEST CHAMBER BUILDINGS
8-FT. SUPERSONIC WIND TUNNEL
KEY PLANS
THIRD FLOOR & ROOF

DRAWN: G.S. & W.R.
CHECKED: W.E.S.
DATE: OCT. 31, 1952
SCALE: 1" = 20'-0"
APPROVED 10-31-52
APPROVED 10-31-52

A9720 A-2 — REV. A
SHEET OF SHEETS



METAL ROLLING DOORS

AS SPECIFIED

DOOR Nº	DIM. "A"	TYPE
65, 69, 70	12'-0"	R.H. MOTORIZED
64, 66, 67, 68	12'-0"	L.H. MOTORIZED
153	8'-0"	R.H. CHAIN OPER'TD.
154	8'-0"	L.H. CHAIN OPER'TD.
156, 157, 216	8'-0"	R.H. CHAIN OPER'TD.
155, 214, 215	8'-0"	L.H. CHAIN OPER'TD.

REVISION	DATE	DESCRIPTION	BY	CKD.	APP.
G	7-23-54	ADDED BLACKBOARD IN Nº 107	JJG		
F	2-26-54	ADDED DOOR Nº 123	JJG		
E	16 OCT. 1953	ADDED LOUVERS DOOR Nº 126.	JJG		
D	31 AUGUST 1953	DOORS Nº 130 & 131 WIDTH INCREASED FROM 3'-4" TO 4'-0"	JJG		
C	1 JUNE 1953	ADDED DOOR TO ROOM IN WEST WING, CHANGED DOORS 135 AND 137. LOCATED DOORWAYS.	JJG		
B	20 MARCH 1953	ADDED DOOR ON SOUTH WALL TEST CHAMBER Nº 1			
A	15 DEC. 1952	CLEAN UP & DETAILS FOR CONSTRUCTION			

JOHN A. BLUME — ARCHITECT-ENGINEER — SAN FRANCISCO

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS
AMES AERONAUTICAL LABORATORY
MOFFETT FIELD, CALIFORNIA

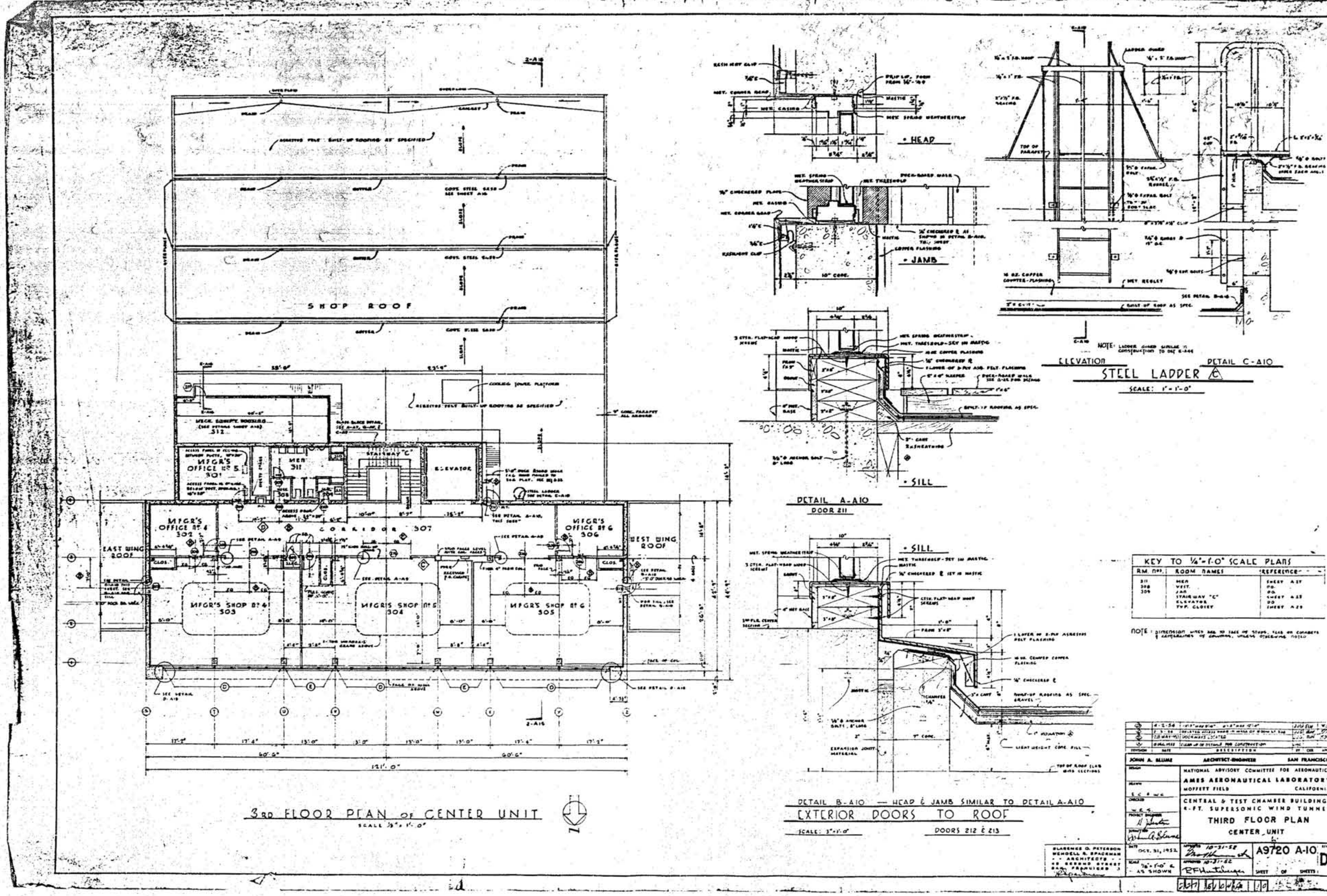
CENTRAL & TEST CHAMBER BUILDINGS
8-FT. SUPERSONIC WIND TUNNEL
FIRST FLOOR PLAN
EAST WING & TEST CHAMBER 1
DOOR SCHEDULE

DRAWN: E.C. & W.R.
CHECKED: W.R.S.
DATE: OCT. 31, 1952
SCALE: 1/8" = 1'-0"

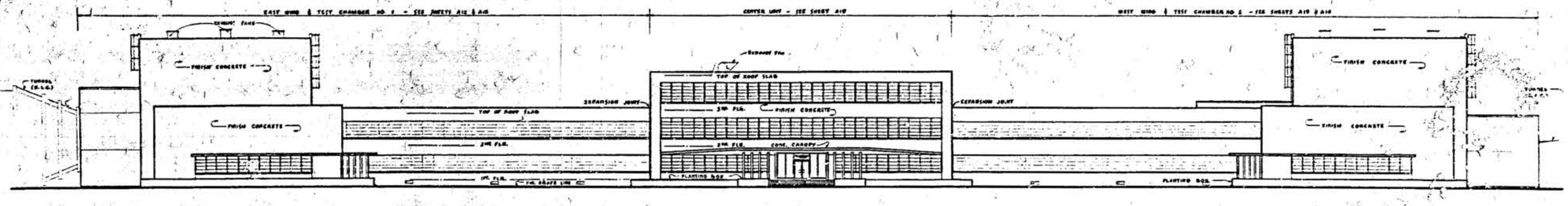
CLARENCE O. PETERSON
WENDELL R. SPACKMAN
ARCHITECTS

A9720 A-4 REV. G

227-5104 A-4
1ST FLOOR PLAN E. WING & TEST CHAMBER 1 DOOR SCHEDULE

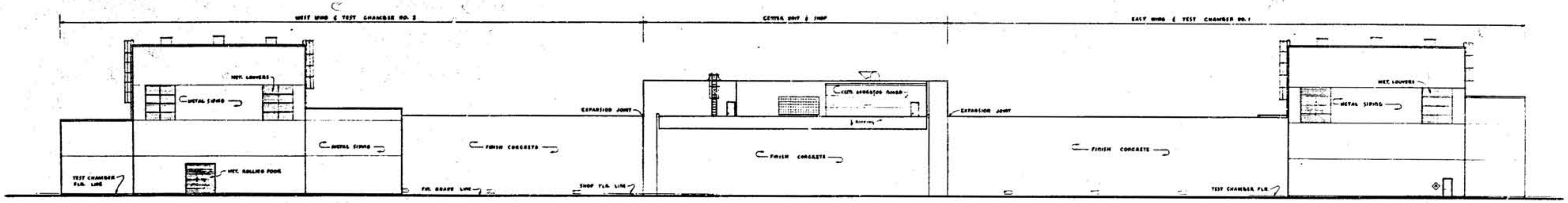


SHOP ROOF
3RD FLOOR PLAN OF CENTER UNIT
SCALE 1/8" = 1'-0"
MFGR'S OFFICE Nº 5 301
MEN 311
STAIRWAY "C"
ELEVATOR
CORRIDOR 307
MFGR'S OFFICE Nº 4 302
MFGR'S OFFICE Nº 6 306
EAST WING ROOF
WEST WING ROOF
MFGR'S SHOP Nº 4 303
MFGR'S SHOP Nº 5 304
MFGR'S SHOP Nº 6 305
60'-0"
121'-0"
HEAD
JAMB
SILL
DETAIL A-A10
DOOR 211
DETAIL B-A10 — HEAD & JAMB SIMILAR TO DETAIL A-A10
EXTERIOR DOORS TO ROOF
SCALE: 3"=1'-0"
DOORS 212 & 213
ELEVATION
DETAIL C-A10
STEEL LADDER
SCALE: 1"=1'-0"
KEY TO 1/4"=1'-0" SCALE PLANS
RM. NO. | ROOM NAMES | REFERENCE
MEN
VEST.
JAN.
STAIRWAY "C"
ELEVATOR
TYP. CLOSET
JOHN A. BLUME ARCHITECT-ENGINEER SAN FRANCISCO
NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS
AMES AERONAUTICAL LABORATORY
MOFFETT FIELD CALIFORNIA
CENTRAL & TEST CHAMBER BUILDINGS
6-FT. SUPERSONIC WIND TUNNEL
THIRD FLOOR PLAN
CENTER UNIT
OCT. 31, 1952
1/8"=1'-0" & AS SHOWN
APPROVED 10-31-52
A9720 A-10
D
SHEET OF SHEETS



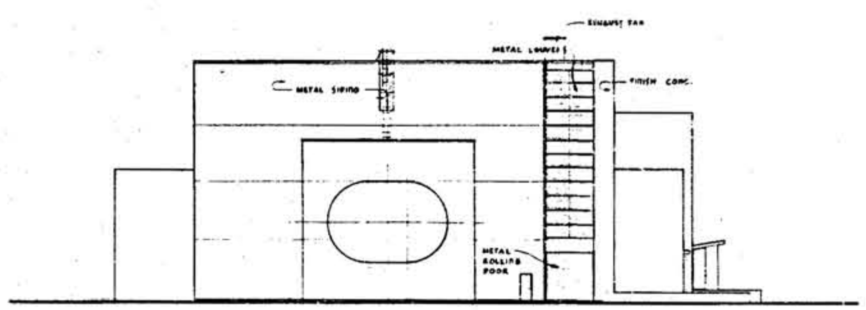
ELEVATION LOOKING SOUTH

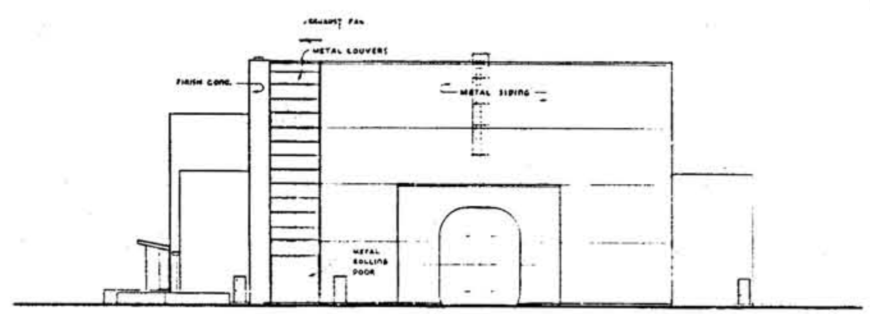
SCALE: 1/16" = 1'-0"



ELEVATION LOOKING NORTH

SCALE: 1/16" = 1'-0"





ELEVATION LOOKING WEST

SCALE: 1/16" = 1'-0"

ELEVATION LOOKING EAST

SCALE: 1/16" = 1'-0"

A9720 A-11

REVISION	DATE	DESCRIPTION	BY	CKR	APP
A	MARCH 22, 1954	ADDED DOOR SOUTH WALL TEST CHAMBER NO. 1			

JOHN A. BLUME — ARCHITECT-ENGINEER — SAN FRANCISCO

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS
AMES AERONAUTICAL LABORATORY
MOFFETT FIELD, CALIFORNIA

CENTRAL & TEST CHAMBER BUILDINGS
8-FT. SUPERSONIC WIND TUNNEL

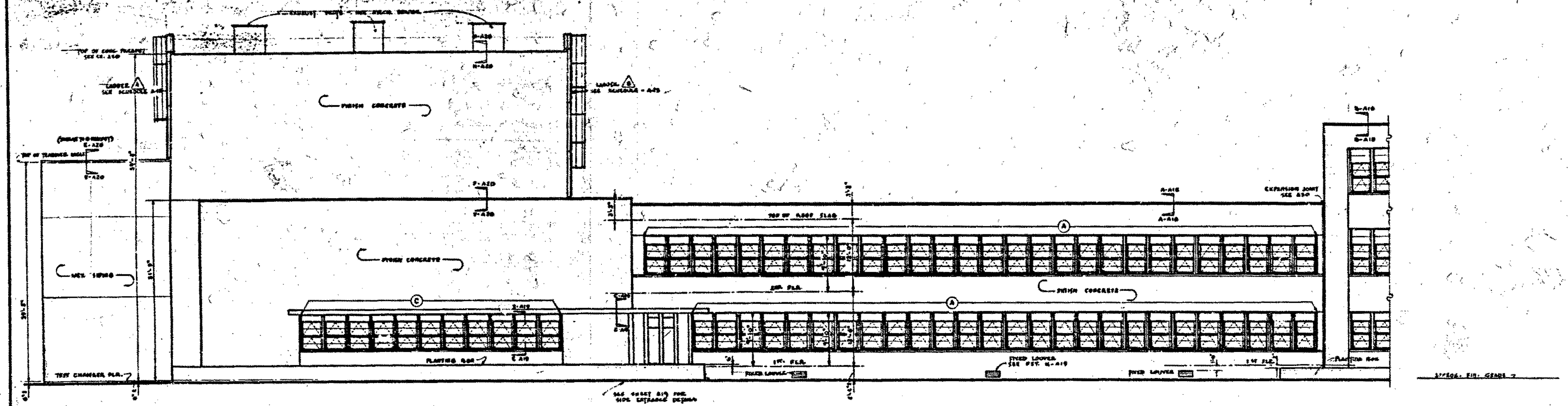
KEY ELEVATIONS

DESIGN:
DRAWN: W.C.
CHECKED: A.R.S.
PROJECT ENGINEER:
SUBMITTED: John A. Blume
DATE: OCT 31, 1952
SCALE: AS SHOWN
APPROVED 10-31-52
APPROVED 10-31-52 R F Huntzinger

A9720 A-11 REV A

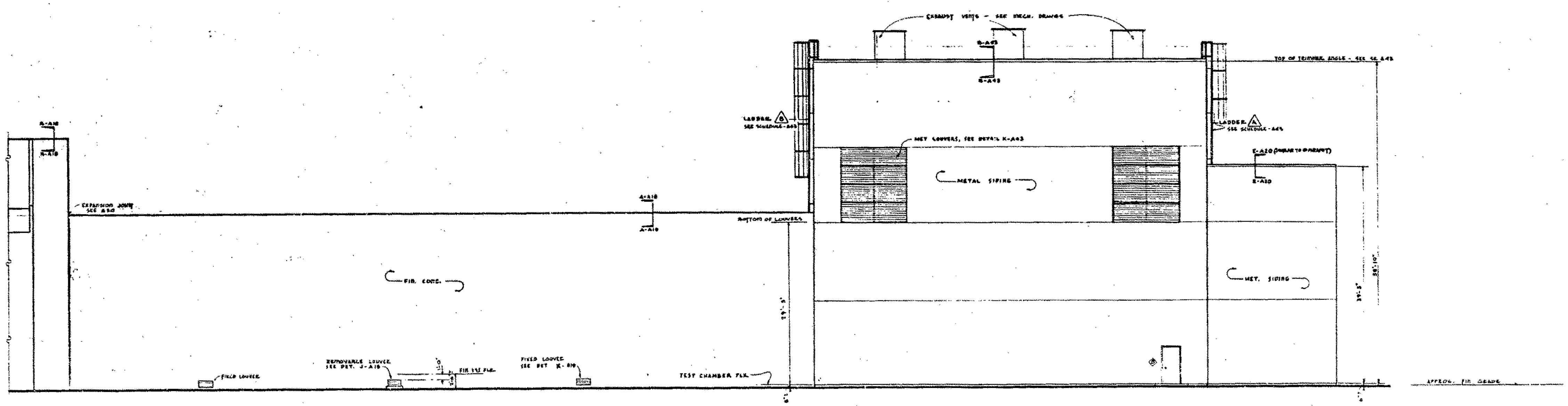
SHEET OF SHEETS

227-5104-A11 KEY ELEVATIONS



ELEVATION LOOKING SOUTH

SCALE: 1/8" = 1'-0"



ELEVATION LOOKING NORTH

SCALE: 1/8" = 1'-0"

REVISION	DATE	DESCRIPTION	BY	CKD.	APP.
B	20 MARCH 1953	ADDED DOOR SOUTH WALL TEST CHAMBER No. 1			
A	17 DEC. 1952	LADDER SYMBOLS CHANGED			

JOHN A. BLUME — ARCHITECT-ENGINEER — SAN FRANCISCO

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS
AMES AERONAUTICAL LABORATORY
MOFFETT FIELD, CALIFORNIA

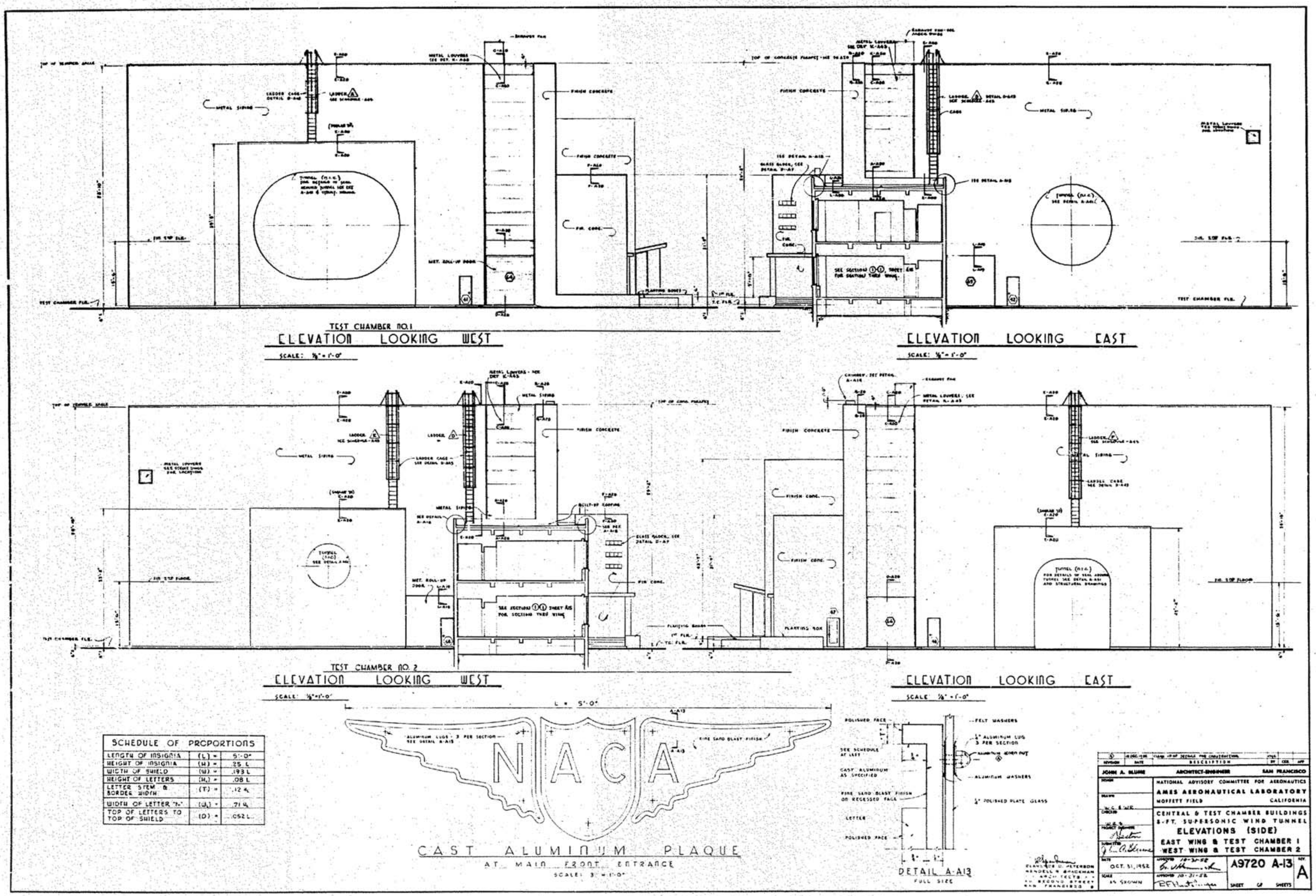
CENTRAL & TEST CHAMBER BUILDINGS
8-FT. SUPERSONIC WIND TUNNEL
ELEVATIONS (FRONT & REAR)
EAST WING & TEST CHAMBER 1

DESIGN:
DRAWN: W.C. & R.F.B.
CHECKED: W.R.S.
PROJECT ENGINEER: [signature]
SUBMITTED: John A. Blume
DATE: OCT. 31, 1952
SCALE: AS SHOWN
APPROVED 10-31-52 [signature]
APPROVED 10-31-52 R.F. Hutchinson

A9720 A-12 — REV. B

SHEET OF SHEETS

CLARENCE O. PETERSON
WENDELL R. SPACKMAN
ARCHITECTS
45 SECOND STREET
SAN FRANCISCO
[signature]



SCHEDULE OF PROPORTIONS		
LENGTH OF INSIGNIA	(L) =	5'-0"
HEIGHT OF INSIGNIA	(H) =	.25 L
WIDTH OF SHIELD	(W) =	.193 L
HEIGHT OF LETTERS	(H_L) =	.08 L
LETTER STEM & BORDER WIDTH	(T) =	.12 H_L
WIDTH OF LETTER "L"	(W_L) =	.71 H_L
TOP OF LETTERS TO TOP OF SHIELD	(D) =	.052 L

JOHN A. BLUME ARCHITECT-ENGINEER SAN FRANCISCO

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS
AMES AERONAUTICAL LABORATORY
MOFFETT FIELD CALIFORNIA

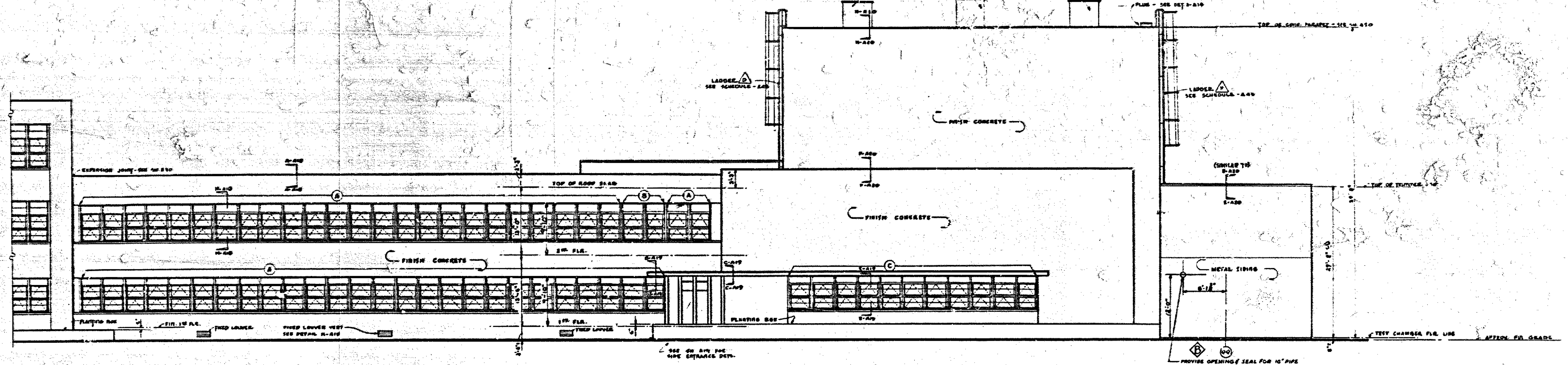
CENTRAL & TEST CHAMBER BUILDINGS
8-FT. SUPERSONIC WIND TUNNEL
ELEVATIONS (SIDE)
EAST WING & TEST CHAMBER 1
WEST WING & TEST CHAMBER 2

DATE OCT. 31, 1952
SCALE AS SHOWN
APPROVED 10-31-52
APPROVED 10-31-52
A9720 A-13
REV. A

146
153
157

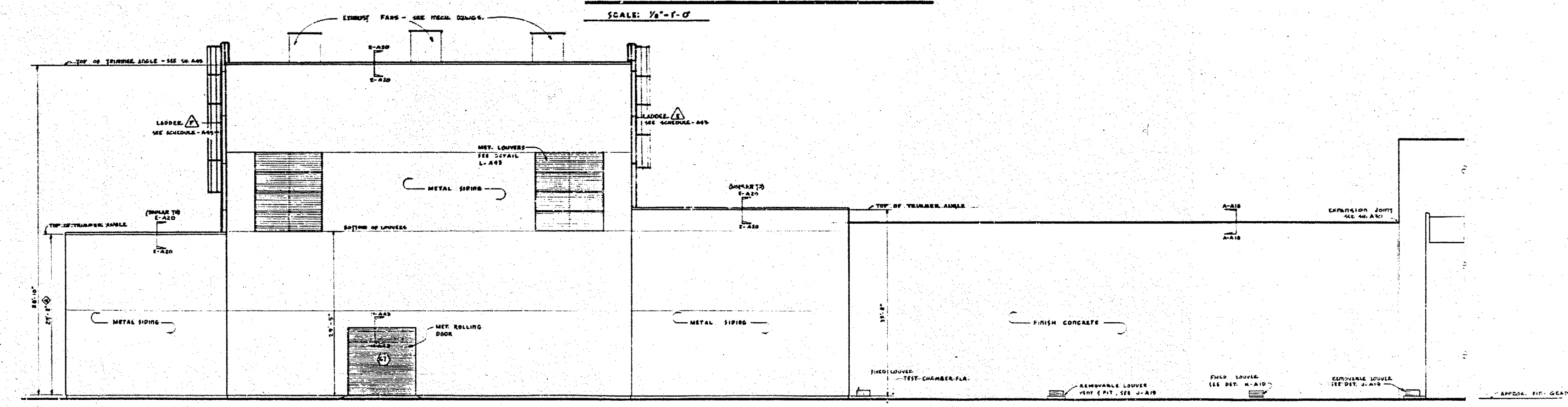
227-5104-A13

N-227A



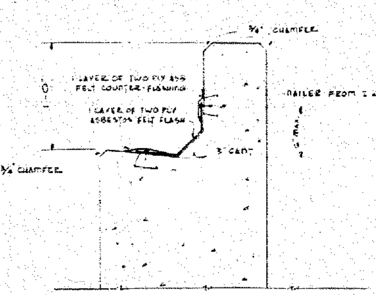
ELEVATION LOOKING SOUTH

SCALE: 1/8" = 1'-0"



ELEVATION LOOKING NORTH

SCALE: 1/8" = 1'-0"



DETAIL A-A14

FLUE ON ROOF OF T.C. № 2

REVISION	DATE	DESCRIPTION	BY	CKR.	APP.
B	11-19-53	10" PIPE OPENING & SEAL ADDED WEST ANNEX.			
A	8 DEC 1952	CLEAN UP OF DETAILS FOR CONSTRUCTION.			

JOHN A. BLUME — ARCHITECT-ENGINEER — SAN FRANCISCO

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS
AMES AERONAUTICAL LABORATORY
MOFFETT FIELD, CALIFORNIA

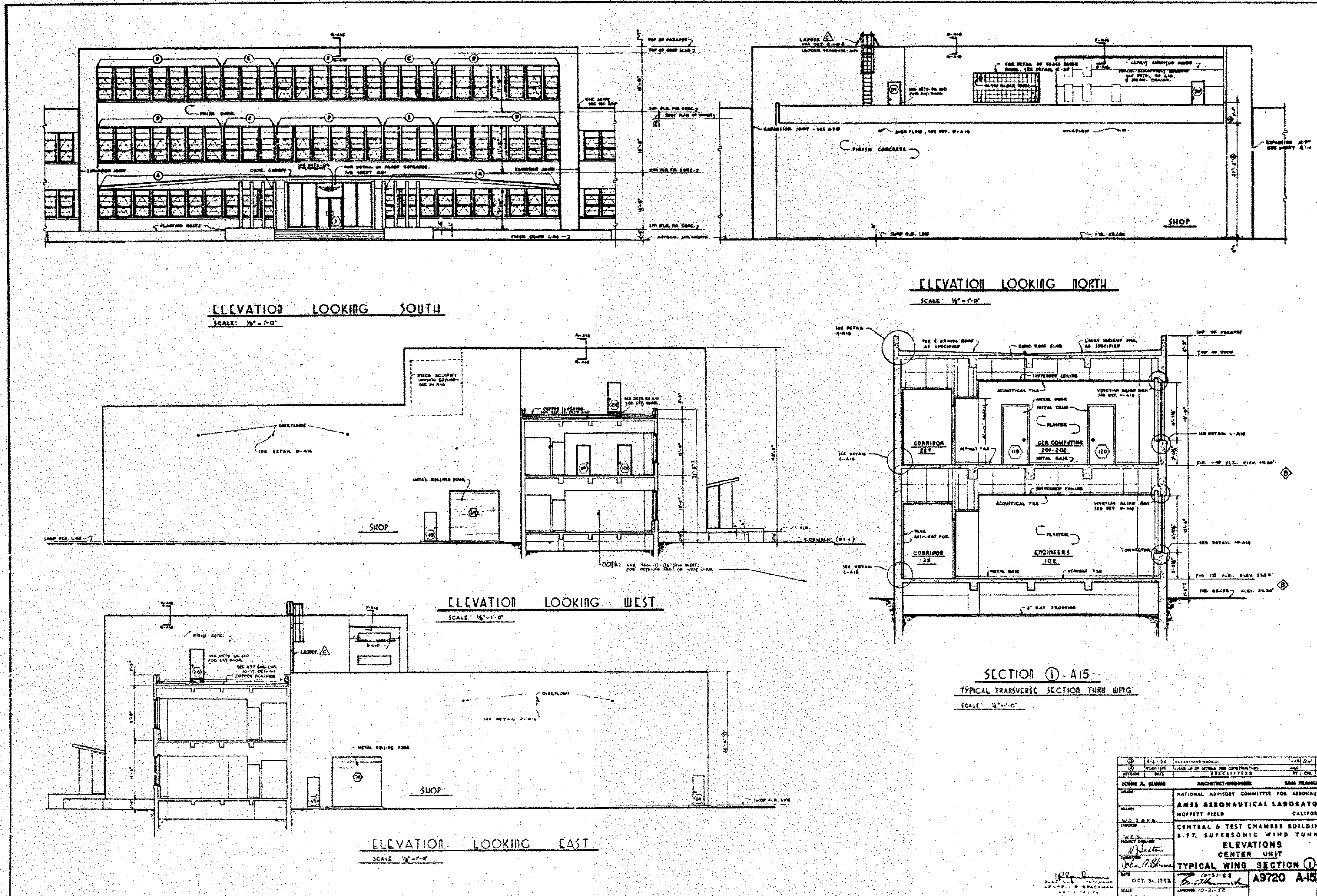
CENTRAL & TEST CHAMBER BUILDINGS
8-FT. SUPERSONIC WIND TUNNEL

ELEVATIONS (FRONT & REAR)
WEST WING & TEST CHAMBER 2

DRAWN: W.G. & R.P.B.
CHECKED: W.R.S.
DATE: OCT. 31, 1952
SCALE: AS SHOWN
APPROVED 10-31-52
APPROVED 10-31-52

A9720 A-14 REV. B

SHEET OF SHEETS



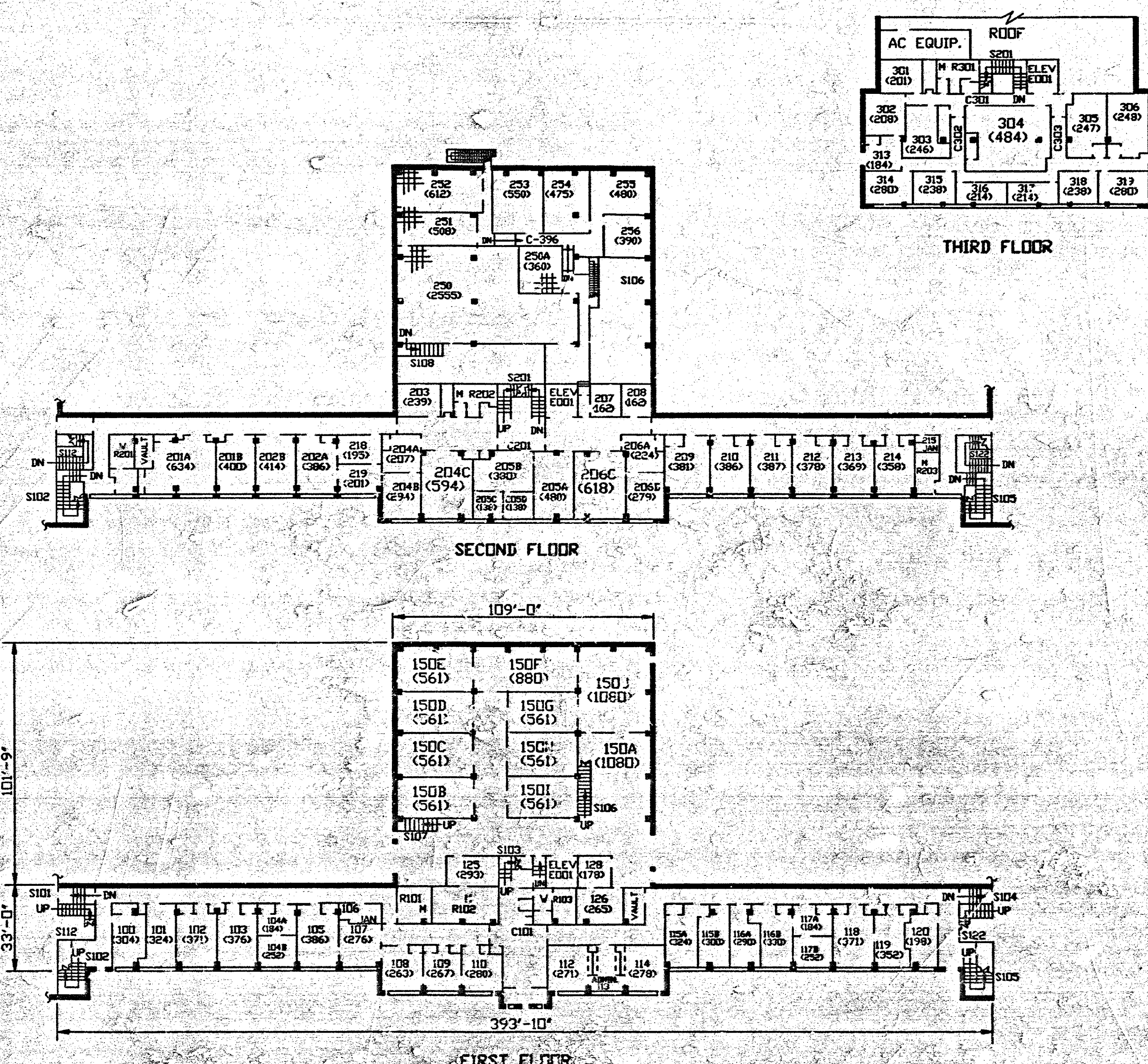
227-5104-A15

N-227

148

INCHES 1 2 3 4 5 6

METRIC 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15



FLOOR	NET USABLE S.F.
FIRST	14,136
SECOND	14,354
THIRD	3,282
TOTAL	31,752

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
AMES RESEARCH CENTER
MOFFETT FIELD, CALIFORNIA

SCALE, FT.	DWG. NO.	REV	DATE	GROSS BLDG. SQ. FT.	TITLE	BLDG. NO.
10 0 10 20 30 40 50 60 70	227-8450-A1	E	8/91	48,735	UNITARY PLAN WIND TUNNEL BUILDING	N-227

SHEET 1 OF 1

LETTER	DATE	REVISION DESCRIPTION	DRAWN	APP.
E	8/91	REVISED PER ECO 34311	FS	LLS
D	11-88	REVISED PER ECO A23276	VAK	
C	12-85	REVISED PER ECO 13251	JLD	
B	6-84	DWG NO. WAS A227-7701-A1	RAD	
A	9-78	REDRAWN ON APPLICON FROM DWG. NO. A13180-C227-1	WAH	

NASA Ames Research Center
Moffett Field, California

UNITARY PLAN
WIND TUNNEL BUILDING

DRAWN: W.HEYER
CHECKED:
INDEX:
MATERIAL:
DESIGN ENGINEER: EGLINGTON
BRANCH: ESEB
REDRAWN 3/23/81
LIMITS UNLESS NOTED: FRAC. DEC. ANG.
APPROVED:
ASSM. DWG. NO.:
APPROVED:
SCALE: 1/32"=1'
A 227-8450-A1
REV: E

A227A1(ACAD/11)