PAPER Nr.: 4

NASA ROTORCRAFT RESEARCH

by

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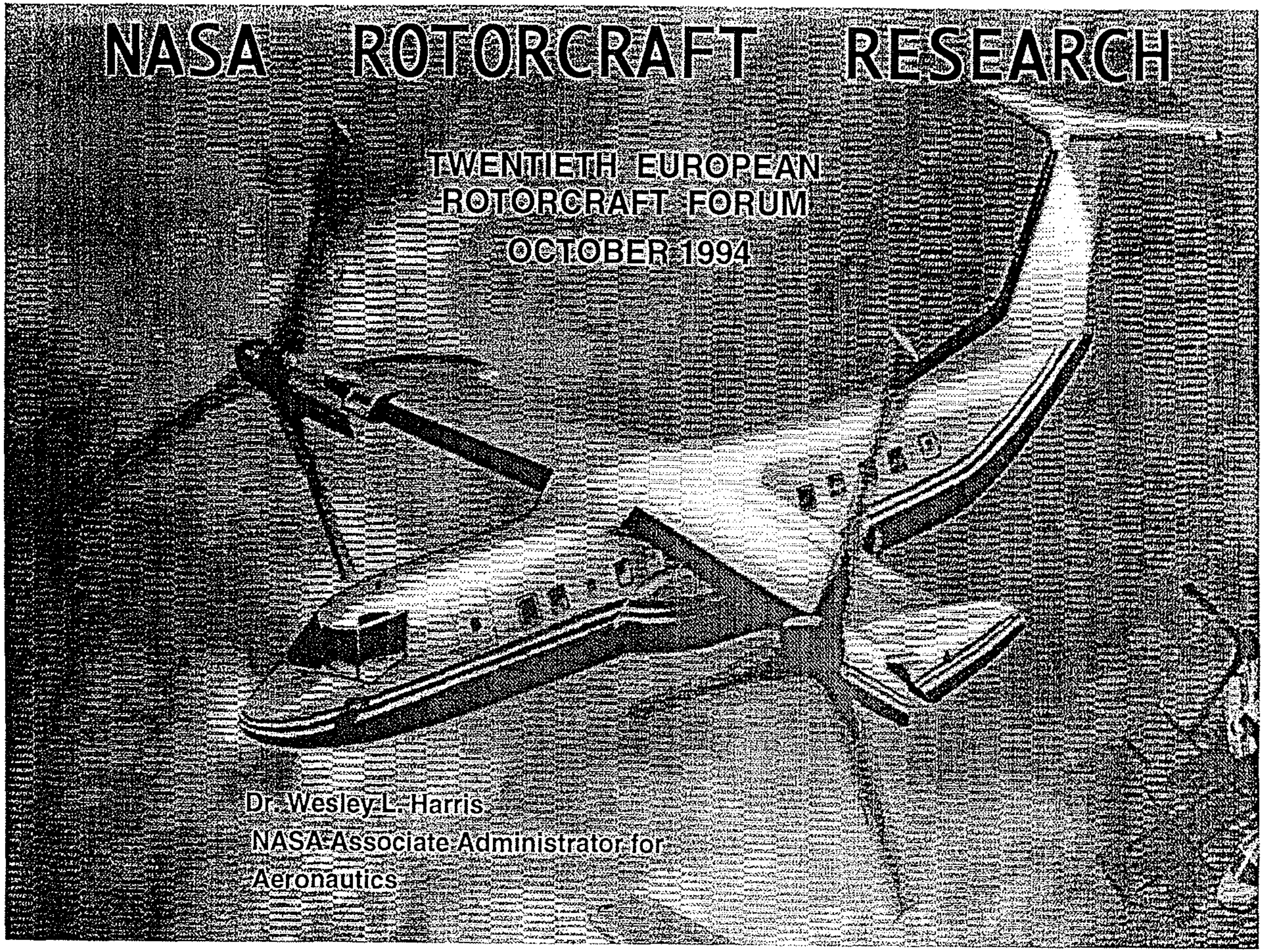
National Aeronautics and Space Administration

TWENTIETH EUROPEAN ROTORCRAFT FORUM
OCTOBER 4 - 7, 1994 AMSTERDAM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NASA AERONAUTICS VISION

Vision

To be a world leader in pioneering high payoff, critical technologies with effective transfer of research and technology products to U.S. industry, the Department of Defense and the Federal Aviation Administration for application to safe, superior, environmentally friendly U.S. civil and military aircraft, and for a safe and efficient National Aviation System.

To stimulate U.S. economic growth and competitiveness in both aerospace and non-aerospace industries.

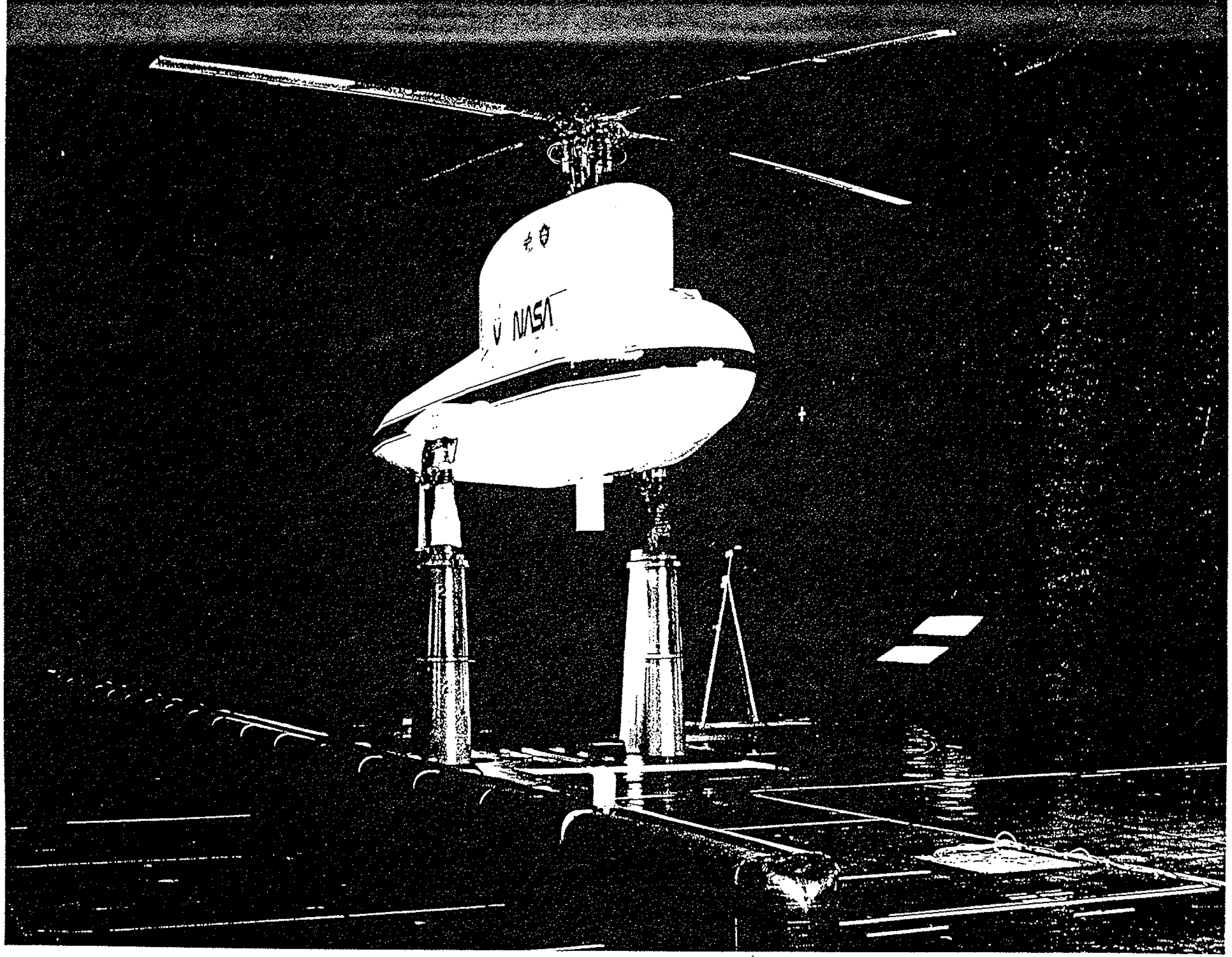

BOEING 360

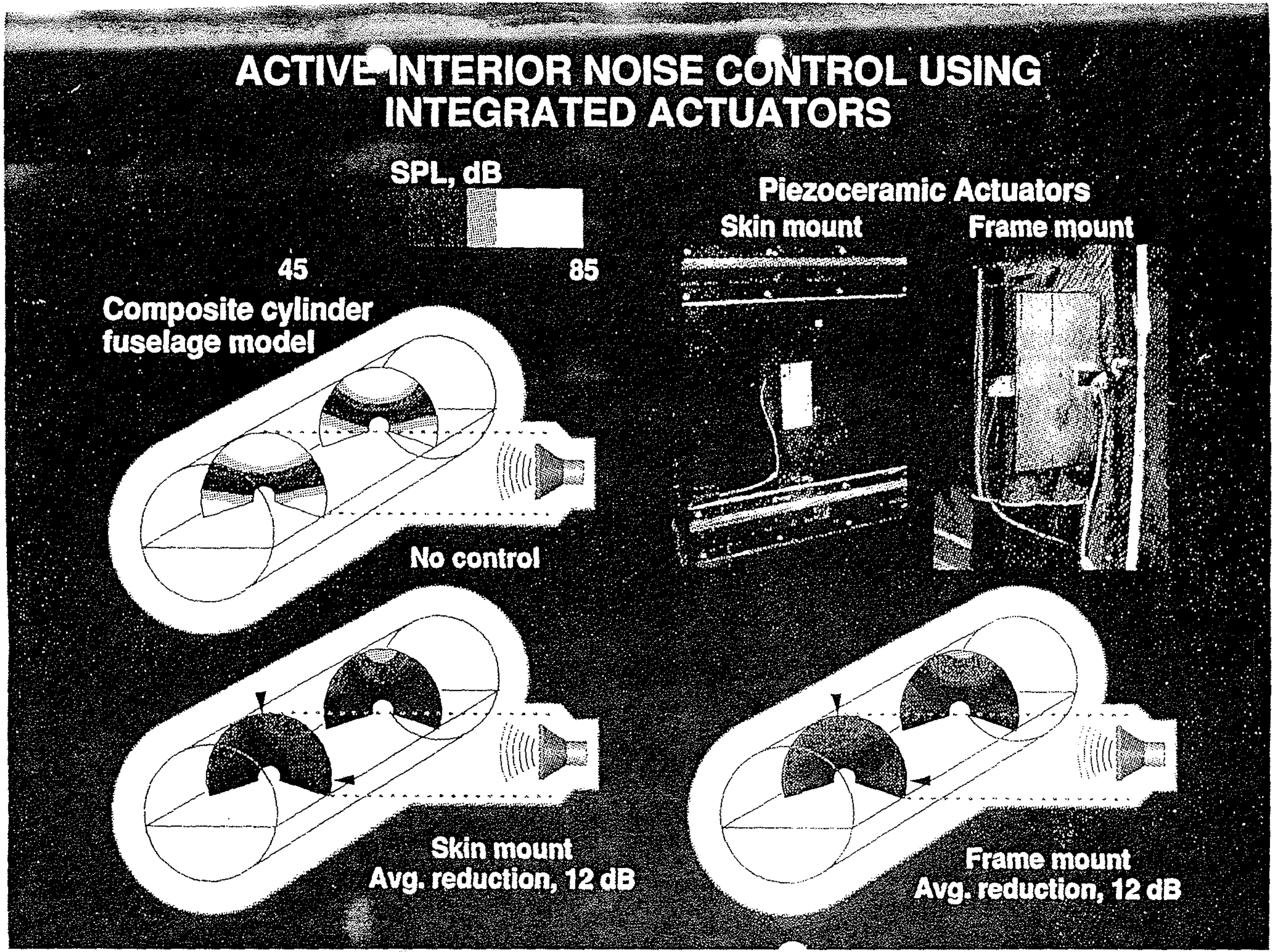
HELICOPTER RESEARCH

NASA's helicopter research consists of:

- Low noise technology
- Improving flight controls and displays
- Icing wind tunnel work
- Computational fluid dynamics advances

Photo shows the Boeing Model 360 advanced technology demonstrator helicopter.
A model scale version of the 360 rotor has been tested by the
Boeing/Army/NASA team in the DNW Wind Tunnel and the 14x22 Wind Tunnel at Langley


NASA


ACTIVE INTERIOR NOISE CONTROL USING INTEGRATED ACTUATORS
SPL, dB
45
85
Composite cylinder fuselage model
No control
Piezoceramic Actuators
Skin mount
Frame mount
Skin mount
Avg. reduction, 12 dB
Frame mount
Avg. reduction, 12 dB

Helicopter External Noise Reduction

- Goal is to reduce blade vortex interaction rotor noise approximately 6 dBA
- Example in picture: <u>Individual blade control (IBC)</u>
  - Each of 4 BO-105 full scale blades outfitted with its own individually-controlled hydraulic actuator
  - IBC actuators replaced the normal rotor pitchlinks and they:
    - » Were capable of plus or minus 3º blade pitch for 2 per/rev input
    - » Allowed IBC input of any combination of harmonics in the 1 to 6 per/rev range
  - Tested in Ames 40 x 80 foot tunnel and acquired extensive data including:
    - » Blade pitch and actuator displacement for all 4 blades
    - » Hub forces and moments
    - » Blade and control system loads
    - » Blade tip acceleration and leading edge pressures
  - Test highlights:
    - » At 170 and 190 knots, rotor showed a 6 to 7 % power reduction compared to normal BO-105 rotor
    - » At 43 knots, tests showed a 9 dBA noise reduction (represents a typical 6 degree approach glide slope). Dominanant vibration harmonic of 4 per rev reduced by 83%.
  - 4 to 6 dBA noise reduction more typical of most test conditions

Interior Noise Reduction

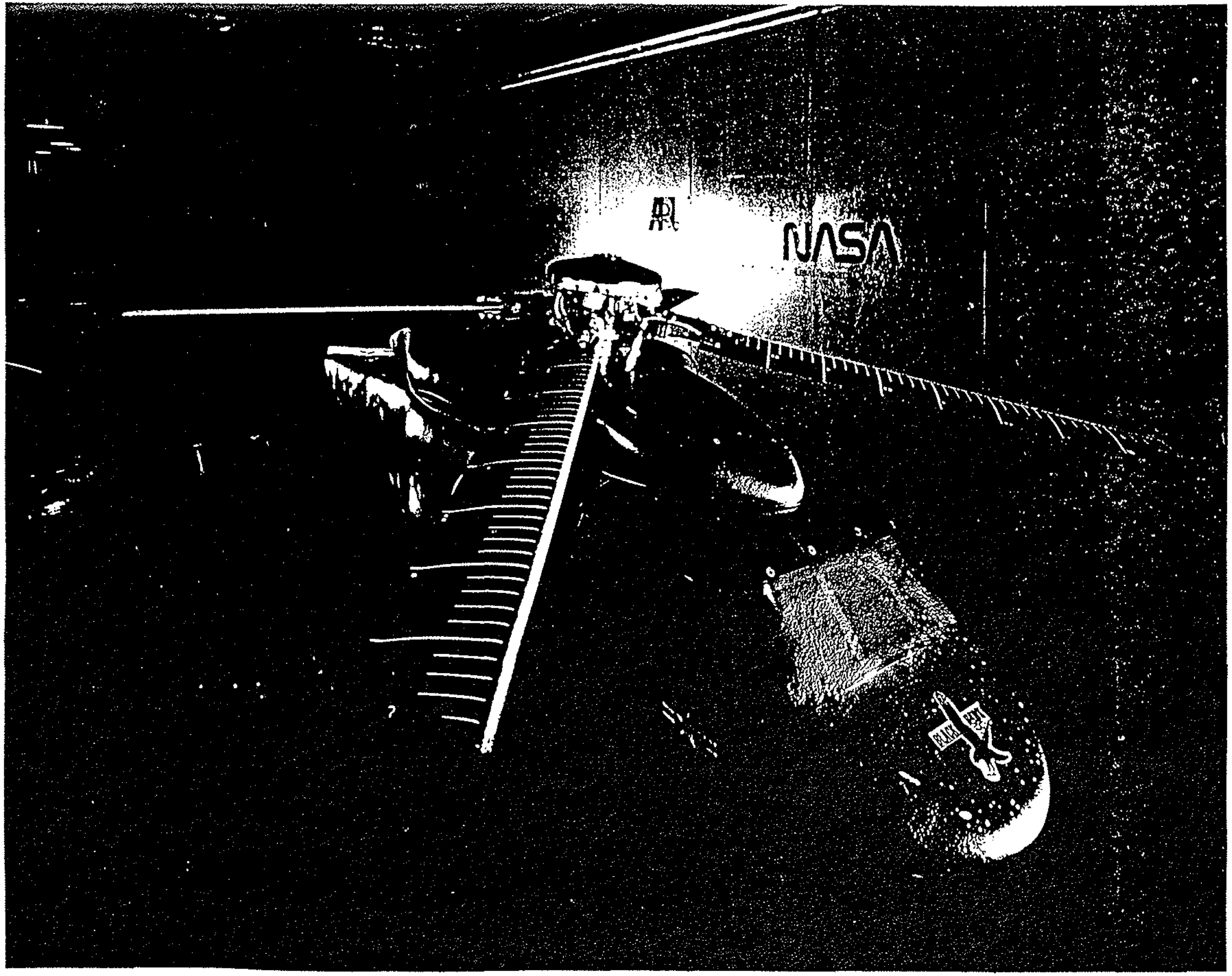
Interior Noise Reduction:

- Goal is to demonstrate a
  - 6 dB overall sound pressure level interior noise reduction
  - 12 dB discrete frequency noise reduction
  - 20 dB transmission vibration reduction
- Passive reduction using structural optimization for noise
  - Optimization of conventional frame/skin design
  - Mass/stiffness variation to realize weak acoustic radiators

CONTROLS, SENSORS AND DISPLAYS:

- Goal is to develop an all weather sensor and cockpit display suite for greatly improved Nap-of-the-Earth flight capability
- **Photo is Ames UH-60 Blackhawk RASCAL helicopter with nose mounted cameras. RASCAL= Rotorcraft Aircrew Systems Concepts Airborne Laboratory**
- NASA Ames is now performing RASCAL flights with the following integrated sensors:
  - » Infra-red cameras (for night vision)
  - » Stereoscopic TV cameras (for range finding)
  - » Differential GPS sensors (for precise ground position) that can provide aircraft position to a cockpit moving map display (FY95 installation)
- Rascal incorporateds a full-color, biocular, helmet-mounted display that can present to the pilot video computer-generated imagery and symbology
  - » It has a wide field of view display
  - » It provides head tracking to allow display stabilization in inertial, airframe and pilot viewpoint reference frames
- NASA Ames is also performing STAR aircraft flights with a laser frequency radar (for wire detection). STAR = US Army UH-60 **S**ystem **T**estbed for **A**vionics **R**esearch.

3961



ICING TESTING

- Icing wind tunnel testing at Lewis Research Center attempts to
  - Determine typical icing buildup patterns on rotors and fuselage and acquire an experimental database
  - Develop alternate icing test methodologies to reduce the amount of in flight testing necessary to certify flight in natural icing conditions

- Current Lewis helicopter icing work actively supports all 4 major US helicopter manufacturers using the one sixth scale test rig

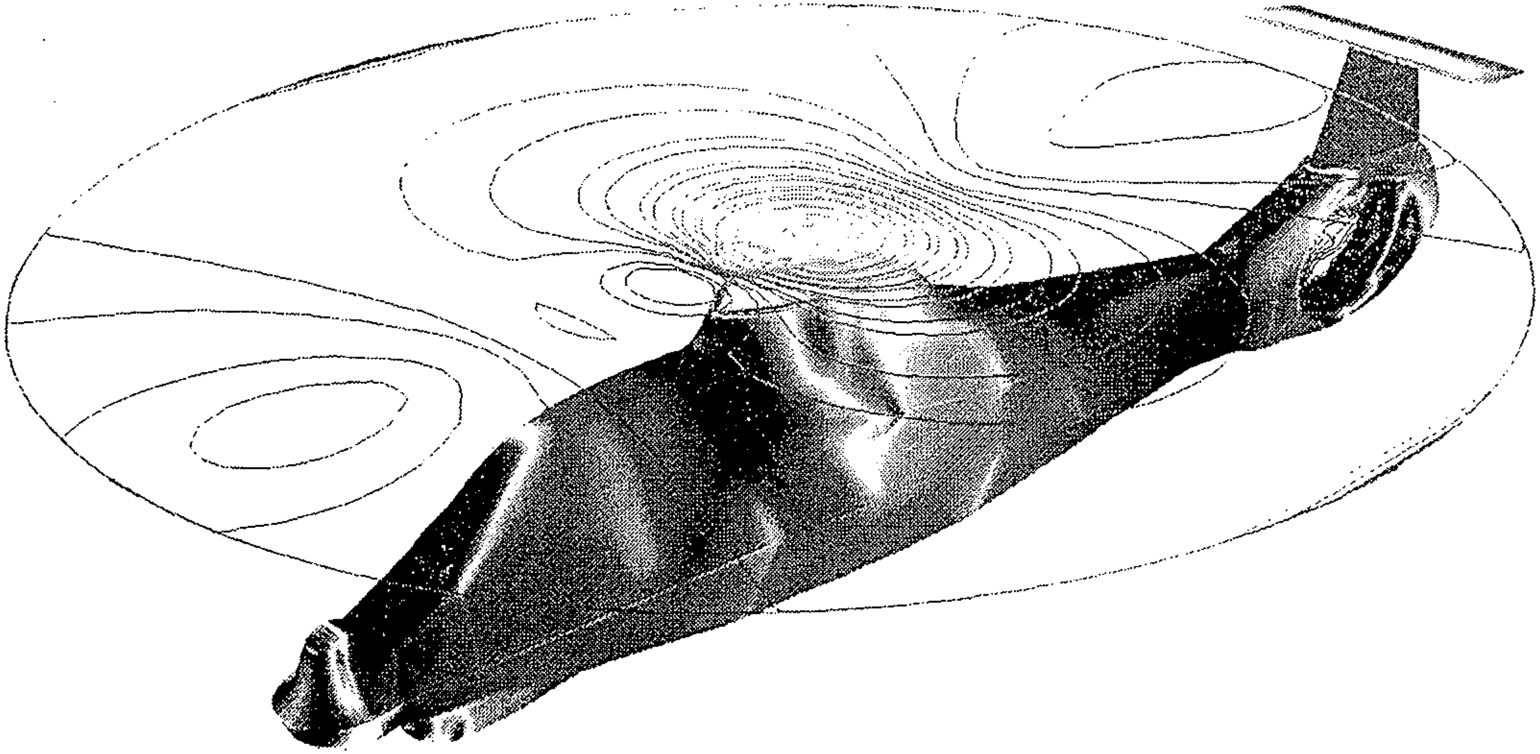
- Pictured:
  - UH-60 Blackhawk icing tests.
  - Note ice accumulation on blades, windscreen and nose cowling

Fuselage Surface Pressure

$M = 0.26$

$Re = 14 \times 10^6$

$C_{T_{rotor}} = 0.009$

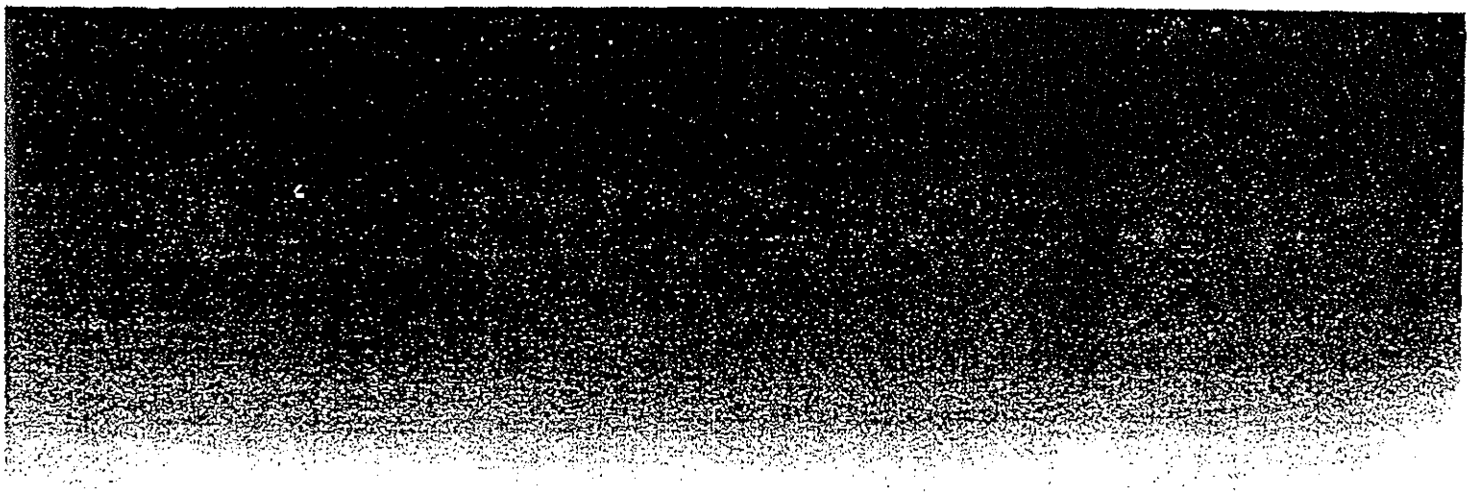


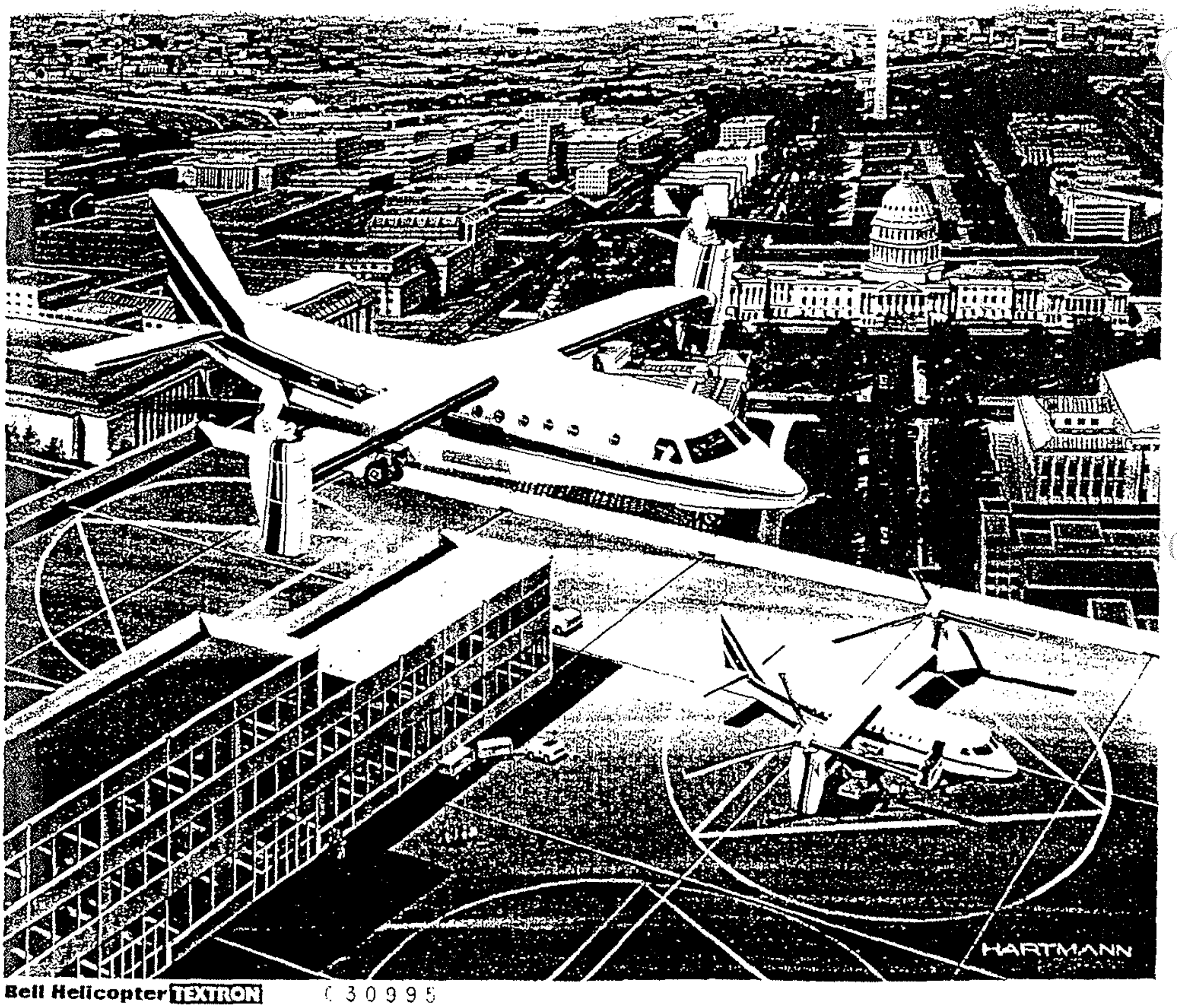
Aeroflightdynamics Directorate

US ARMY
AVIATION AND
TROOP
COMMAND

Rotorcraft Computational Fluid Dynamics

- Goal is to develop computational tools to accurately predict the complete helicopter flow field including:
  - All moving and non-moving components (ie, rotors and fuselage)
  - Rotor/body interaction and unsteady blade loads
  - Acoustics
  - Complete pressure distribution at all surfaces
  - Near and far field flows
- Example shown: Fuselage surface pressure map of the RAH-66 Comanche helicopter obtained using:
  - Thin-layer Navier Stokes equations
  - Structured grids for use as implicit solvers in viscous regions
  - Unstructured grids for use in rotor wakes
  - Central difference spatial terms
  - Implicit pentadiagonal time advance
  - Actuator disk to model rotor effect





Bell Helicopter TEXTRON C 30995

CIVIL TILTROTOR RESEARCH

NASA's civil tiltrotor research consists of:

- Low noise technology
- Increased engine contingency power
- Improved flight controls and displays

Picture: Artist's conception of 40 passenger Civil Tiltrotor making a vertical takeoff from a rooftop vertiport near the US Capitol Building in Washington, DC

External Noise Reduction

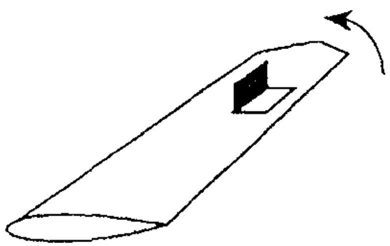
Some Low Noise Rotor Concepts

Porous Leading Edge

Rotor with Porous Leading Edge

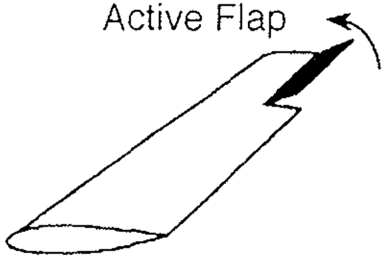
Forward-Swept Rotor

Vortex Alleviation

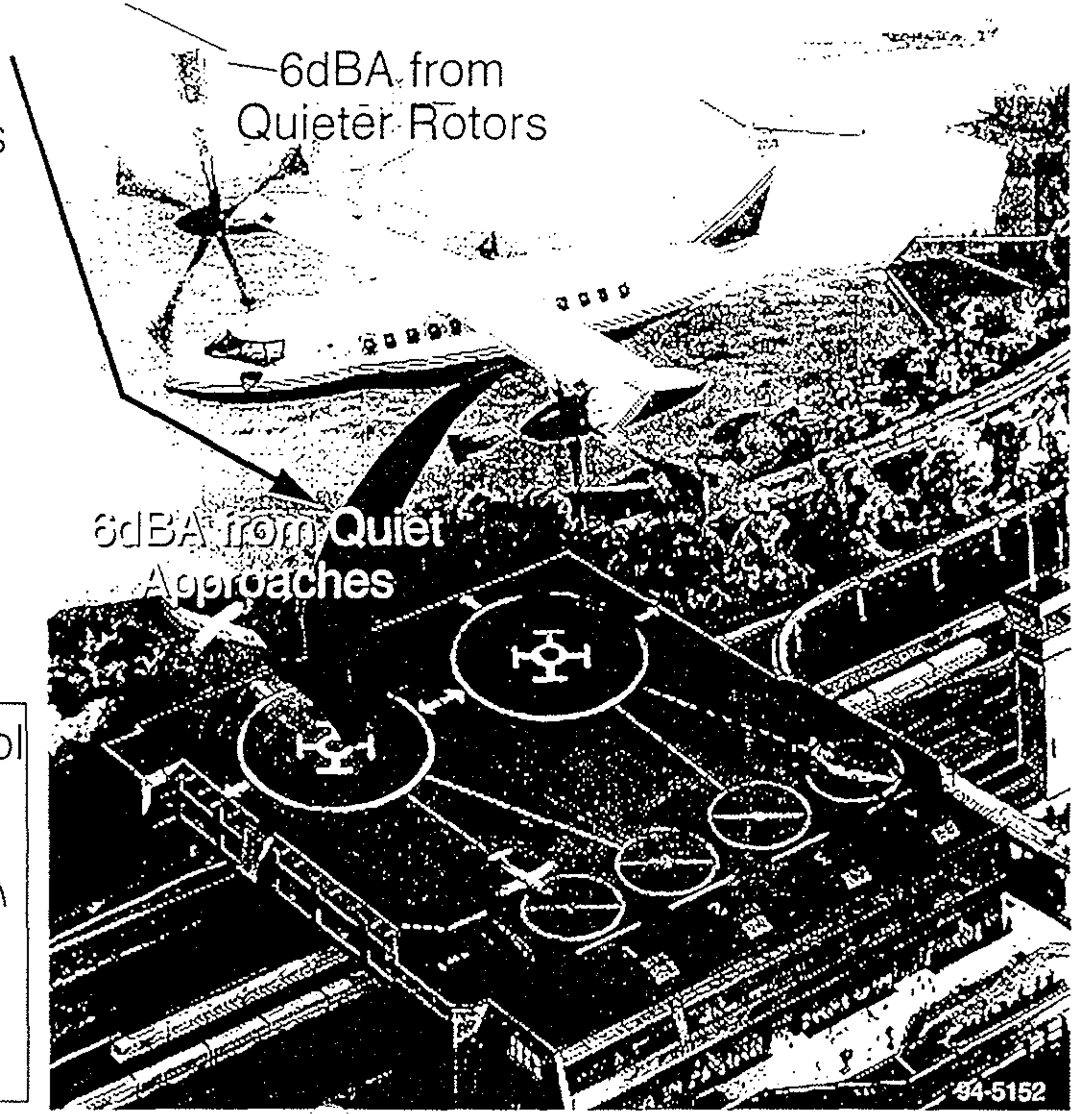


Active Flap Control

Noise Reduction by Active Flap

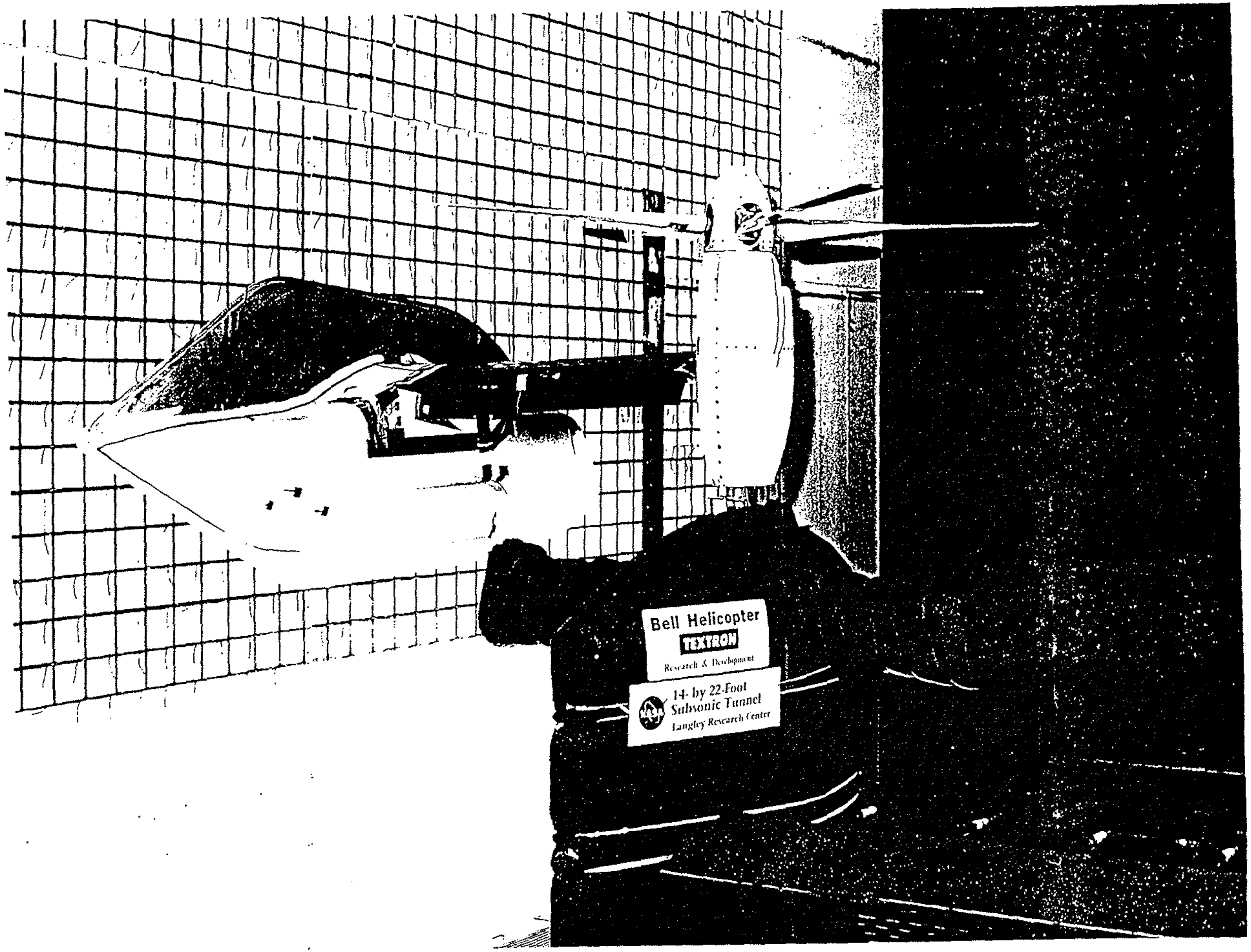


12dBA Total
Noise Reduction



Tiltrotor External Noise Reduction

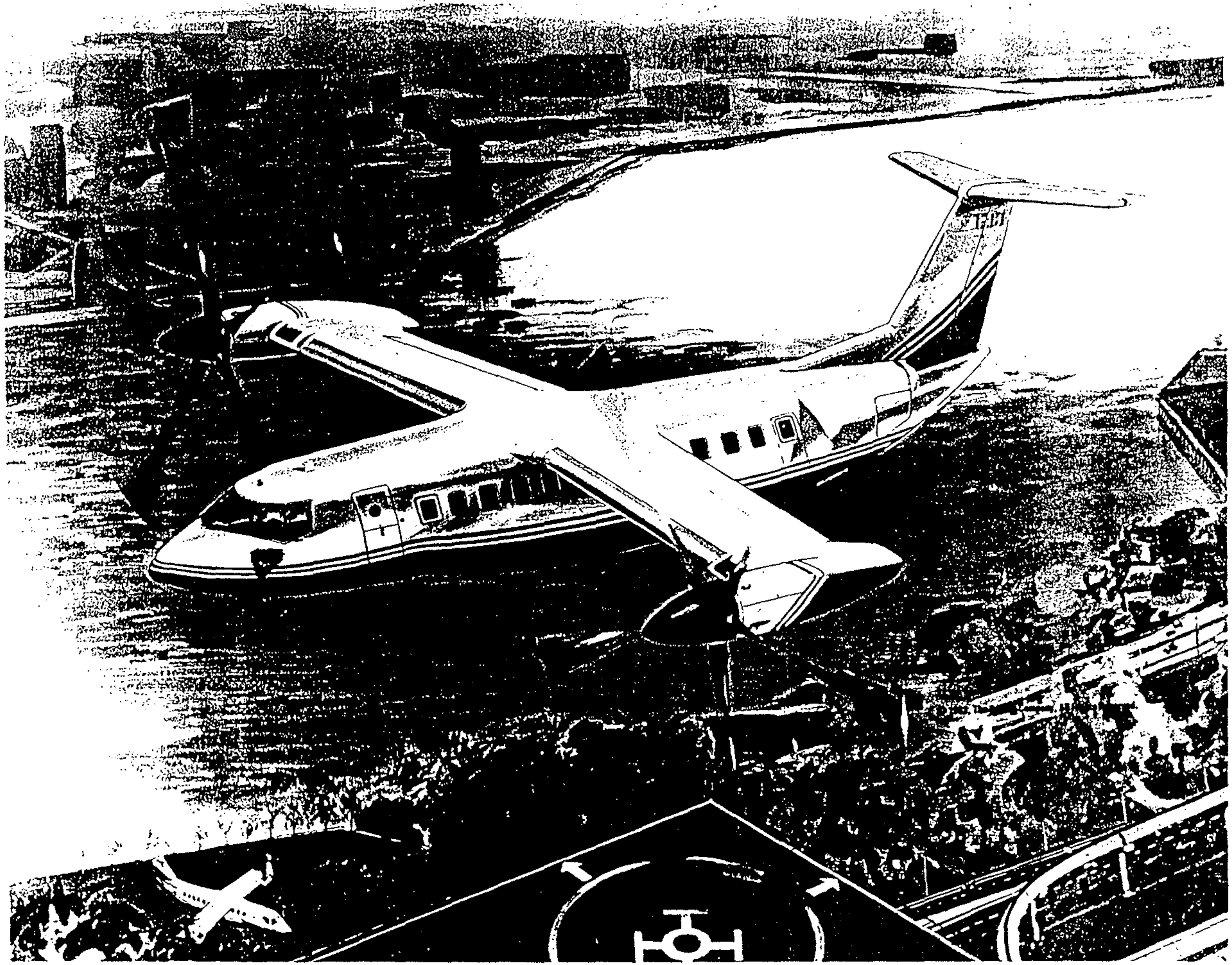
- Goal is to reduce tiltrotor overall approach noise outside a 40 acre vertiport controlled area to meet the community noise constraint of 65 DNL by:
  - A 4 to 7 dBA reduction from a new, quieter rotor
  - An additional 4 to 7 dBA reduction from flying quieter approach profiles (steep 9-15 degree approaches with varying descent rate, airspeed and glide path angle to avoid the maximum region of blade vortex interaction).
- Some low noise rotor concepts being investigated:
  - Porous leading edge
  - Forward swept rotor
  - Vortex alleviation through spoiler mechanism
  - Active flap rotor
- Following selection and small scale wind tunnel testing of the most promising designs, proceed to medium scale and then large scale wind tunnel testing.


Bell Helicopter
TEXTRON
Research & Development
14- by 22-Foot
Subsonic Tunnel
Langley Research Center

Tiltrotor External Noise Reduction

Example picture:

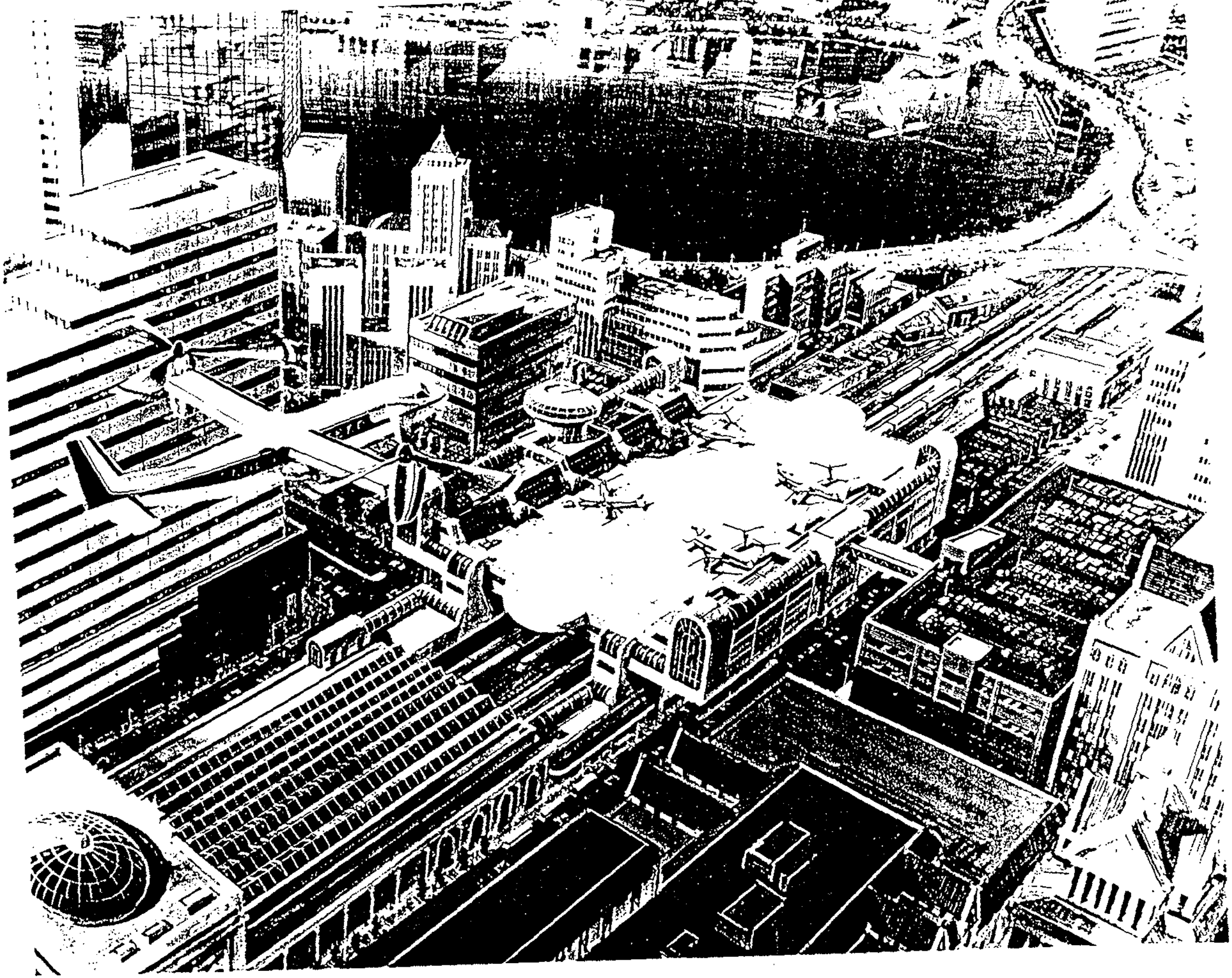
- Recent test of a 3 bladed V-22 model
- Tested in July in Langley 14 x 22 foot tunnel
- Was a NASA, Army, Bell joint program (with 50% industry cost sharing)
- Was the most comprehensive tiltrotor combined acoustic / aerodynamic data base acquired to date with extensive acoustic map in tiltrotor conversion corridor
- Laser velocimeter measurements of the flow field during blade vortex interactions (BVI):
  - » Improved our physical understanding of BVI
  - » Aided the validation of rotor CFD prediction codes



CONTINGENCY ENGINE POWER FOR TILTROTORS

- Goal is safe and cost effective one engine inoperative emergency power capability for the civil tiltrotor
- NASA is identifying and analyzing a variety of promising candidates, including:
  - Engine operation beyond normal redline for short duration
  - Variable cooling airflow
  - Variable turbine geometry
  - Water injection
- We plan to perform preliminary design and select concepts for testing
- The final step is to design and build one or two concepts for large scale testing

Picture: Five-bladed Civil Tiltrotor near vertiport



TILTROTOR CONTROLS, SENSORS AND DISPLAYS

NASA is developing advanced tiltrotor controls, displays and procedures to maximize pilot efficiency during complex low noise flight profiles under all weather conditions in congested terminal areas:

- The goal is to demonstrate Level 1 handling qualities during steep (9 to 15 degree) approaches with varying descent rate, airspeed and glide path angle to avoid the maximum region of blade vortex interaction noise
- The steep angle approaches will be complicated by obstacle (ie skyscrapers, radio towers) avoidance in congested terminal areas located in downtown city areas
- We are now performing XV-15 and V-22 tiltrotor aircraft simulations in the Vertical Motion Simulator (VMS) to develop initial procedures
- We will perform an advanced tiltrotor simulation on the VMS with the final integrated set of displays, controls, low noise rotors and contingency engine power around the year 2000

Picture: Civil Tiltrotor making steep, low noise approach to busy downtown vertiport

FUNDING

For the 1995 to 2000 timeframe, helicopter and tiltrotor funding is approximately $30 million per year

CONCLUSION

NASA is vigorously pursuing:

- Reductions of external and internal noise
- Advances in flight controls and vision- enhancing sensors and displays
- Improved computer analysis techniques for fluid dynamics and icing prediction
- Increased contingency engine power for the civil tiltrotor

We hope that our work substantially contributes to quieter communities and to the comfort and convenience of the world's passengers and crew as they fly the helicopters and tiltrotors of the 21st century.