



# History of 14x22 Fan Blade Maintenance

59<sup>th</sup> Meeting of the Subsonic Aerodynamic Testing Association

14- by 22-Foot Subsonic Wind Tunnel

NASA Langley Research Center

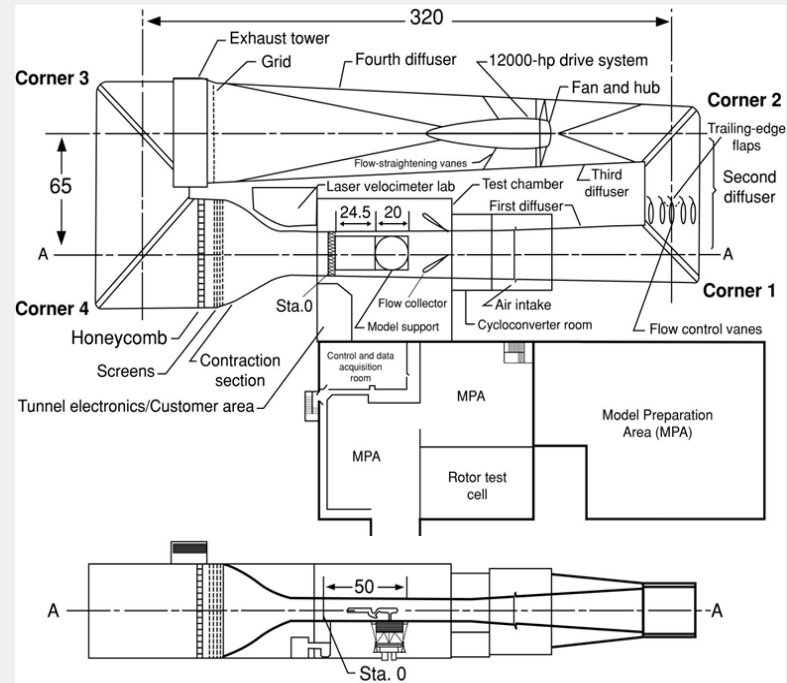
Chris Cramer, 14x22 Operations Manager

# Agenda

1. Facility Overview
2. Goals
3. Fan Description
4. History of 14x22 Fan Blades
5. Current Maintenance Plan
6. Challenges
7. Repair History and Process
8. Current Developments

# Facility Overview

- Test Section Size
  - 14.5 ft x 21.75 ft x 50 ft
  - 4.4 m x 6.6 m x 15.2 m
- Closed Jet
  - Max Speed: 348 ft/sec (106 m/sec)
  - Max unit Reynolds Number:  $2.2 \times 10^6/\text{ft}$  ( $7.2 \times 10^6/\text{m}$ )
- Open Jet
  - Max Speed: 275 ft/sec (84 m/sec)
  - Max unit Reynolds Number:  $1.7 \times 10^6/\text{ft}$  ( $5.6 \times 10^6/\text{m}$ )





# Goals

- Seeking assistance from other tunnels with wooden blades to learn from their experience with monitoring blade health and extending blade lifespan
  - Looking to implement modern blade health monitoring tools and processes into 14x22 maintenance plans
- Full blade removals are done every 10 years and the last full blade pull was in mid-2015 during the motor rewinding
  - Full blade removals are inherently high-risk and 14x22 does not have any spare blades
- 14x22 has decided to delay fan blade removal until FY26 in hopes of gathering information to be better prepared for upcoming inspections

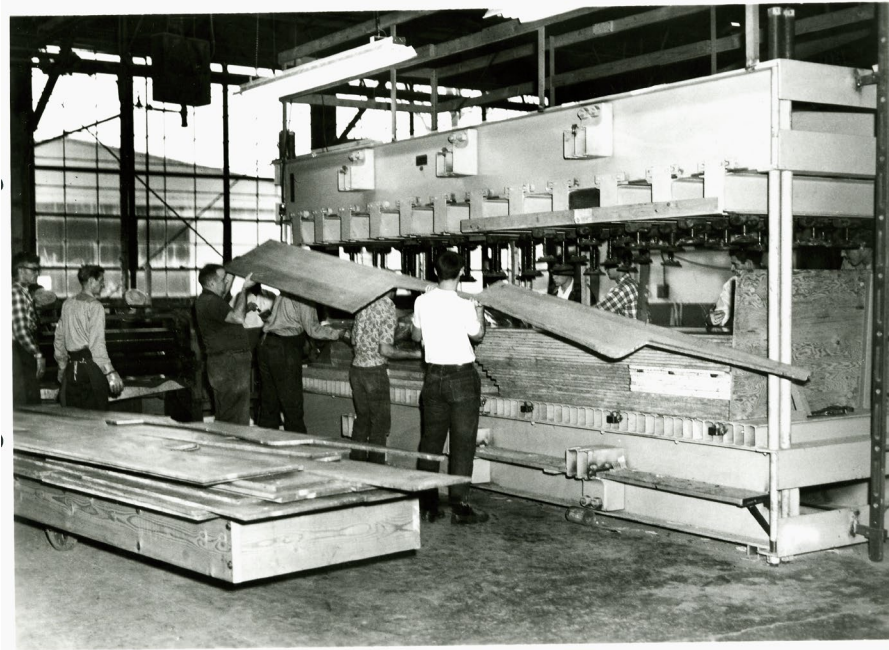
# Fan Blade Description

- Fan blade area is 40 feet (~12 m) in diameter
- Attached to a solid state cyclo-converter type drive with 12,000 HP synchronous motor
- 9 wooden blades total, original construction
  - Sitka Spruce
  - Coating contains multiple layers of “Hetron 72” resin and a thin layer of fiberglass
  - Leading edge is covered with a Celastic and GACO rubber coating for protection
  - Each blade is 16 feet (~5 m) long and weigh roughly 650 pounds (~295 kg) each or 2200 lbs (~1000 kg) with blade box attached
- Each blade is retained in a mounting box with 4 pins that go through the box and the blade
  - Each pin is held in place by two spanner nuts



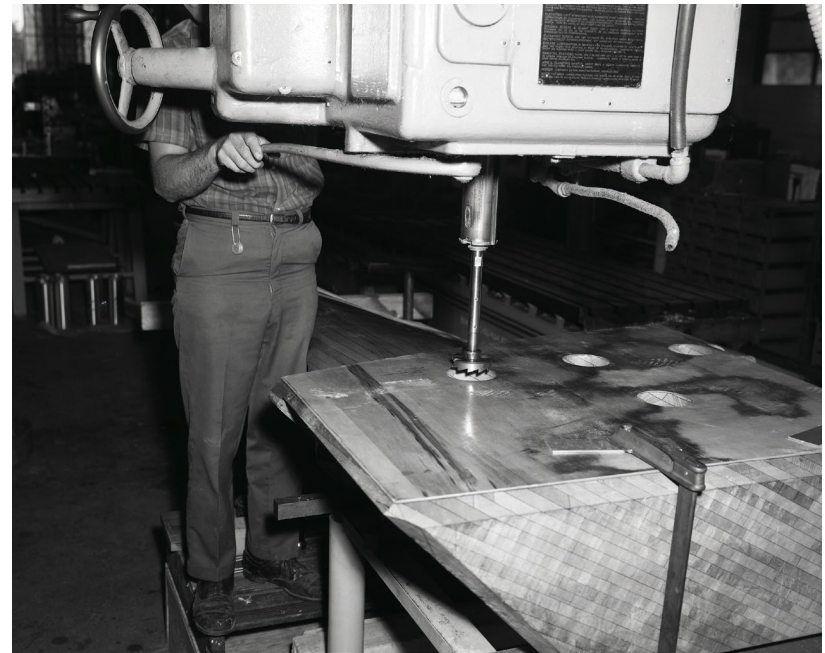
# History of the 14x22 Fan Blades

- Contract was awarded to the Gamble Brothers, a furniture company, in Louisville, KY on May 20, 1968.
- Manufactured offsite with precise specifications and oversight from NASA, cost ~\$150k at the time
- Finished construction in March of 1969



V/3706 3/1969

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# Fan Blade Maintenance Plan History

- First removal of the blades was in 1996
  - Visual inspections, natural frequency testing, and overlay mapping were done annually up to this point
  - Blades determined to be in great condition
  - Recommended pulling blades again in 10 years
  - Blades were removed again in 1999 and 2001
- Memo Dated July 22, 2006 attempted to officially define the maintenance plan going forward
  - Established plans for annual and 10-year inspections
  - Largely the same methods in use today
- Blades were removed again in 2015 when the motor was removed for rewinding
  - No changes made to the existing maintenance plan
  - Restarted the “clock” for next 10 year pull



Fan Blade Removal 2015

# Current Maintenance Plan

- Daily
  - Technician SOPs
    - Both tactile and visual, limited to the reach of the technician
    - Tunnel circuit FOD inspection
    - Performed before wind-on operations
- Annually during maintenance period, Dec - Jan
  - “Hub to floor” visual and tactile blade inspection with scaffolding
  - Natural frequency bump testing of each blade
  - Checking blade tip clearances and tracking
  - Ultrasonic inspection following procedure for 16-Foot
- Every 10 years
  - Full blade removal
  - Full blade root to tip visual and tactile inspection
    - Monitor crack growth with use of “templates”
  - Magnetic particle (MT) inspection of blade box/pins
  - Repair/refinishing of blades, if needed



Blade with blade box removed



Butt-end of one of the blades

# Removal Preparations





# Lifting and Blade Box Removal



# Fan Blades during Motor Rewinding (2015)



# Challenges

- Fan blades exposed to moisture/humidity/temperature changes due to outside weather changes
- High risk of damage in removing fan blades
  - Knowledge or experience with removing fan blades is often lost due to lacking documentation and turnover of employees
- Fan blade inspections during removal are surface level only
  - No internal structure analysis is performed
  - Ultrasonic testing results proven to be lacking
- Inspection processes have been largely the same since original construction
  - Have not been updated with modern methods
- Lack of experience with analyzing structural integrity of wooden fan blades
- Information is scattered between many different sources (facility, maintenance, etc.)
- Daily visual/tactile inspections can only be done up to a certain height
  - Access to the blade root and hub area requires scaffolding
- Bump testing was unable to detect differences with recent repair
  - Historical data collected, but difficult to compare to past results due to differences in test setup
- Celastic/GACO material on leading edge can “hide” damage until it’s more extensive



# Repair History since 2015

- September 2015: Broken window incident
  - Numerous small dings and scratches
- August 2016: Second broken window incident (laser)
  - Numerous small dings and scratches on LE and at the root
- November 2016: GACO Material bubbling
- June 2017: Minor impacts and missed damage from previous window incidents
- Typically, some level of minor repair is needed during annual inspections and done with blades in place: cracks, delamination, exposed wood, or damaged coating
  - 2018: Small cracks developing at the root, minor delamination
  - 2019: GACO material impact damage
  - 2020: Minor damage due to scaffolding rubbing
  - 2021: Exposed wood on blade tips, minor delamination
  - 2022: Minor impacts on surface of blade
- March 2025: Leading edge/dry rot repairs



Crack found during 2018 inspection

GACO Coating  
Damage from Window

# Leading Edge/Dry Rot Damage Repair: March 2025

- During daily checks, it was noticed there was a soft spot underneath the Gaco coating on the leading edge of blade 1
- Model shop was called to inspect the area
- After removing the coating, more extensive damage was discovered
  - Evidence of moisture damage and dry rot
- Repair was done with the blades in place
- The model shop recommended a more thorough inspection of each blade during the next blade removal
- Longer term repair can be completed with better access to area



Leading Edge Damage 2024

# Repair Process

1. Removed Celastic and GACO coating from leading edge
  - Approximately 8 inches from the blade tip
2. Removed compromised wood using a Dremel tool with a rough spur bit
3. Area was cleaned with acetone and a clean rag
4. Evercoat Lite-Weight body filler was used to fill voids from where wood was removed
5. Once fully cured, the filler was sanded smooth to reshape the leading edge
6. Three layers of 0.005” thick fiberglass (style 1522) was applied with West System 205 resin/206 hardener
7. One additional layer of fiberglass was applied on top
8. Two coats of GACO rubber were applied to the surface



Fiberglass Repair

GACO Application



# Current Developments

- Elios 3 Drone
  - LiDAR, 4K Camera, IR Camera, Ultrasonic testing
  - LiDAR scans completed in place may be able to detect external changes over time
- Reaching out to other tunnels with wooden blades and LaRC NDE Branch
  - Looking into x-rays of each blade to investigate internal structure
  - Using 16-FT tunnel blade for testing techniques
- Reached out to Mariner's museum head conservator for potential techniques/contacts
  - Connecting us with a contact at the Smithsonian Air and Space Museum
- Staggered blade pull to accommodate schedule changes and other Langley tunnel maintenance schedules
  - This gives an opportunity to refine analysis techniques on first set and apply lessons learned



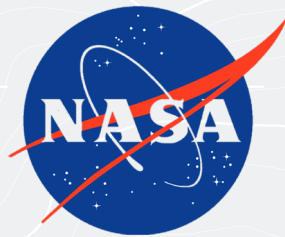
**Blades Refinished in 2015**

# Questions/Comments?

Chris Cramer, 14x22 Operations Manager



Thank you.



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