National Aeronautics and Space Administration

Sustainable Flight Demonstrator (SFD) Project

National Academy of Sciences Aeronautics and Space Engineering Board (ASEB)

October 17, 2023

Brent Cobleigh, NASA SFD Project Manager

Image Credit: Boeing

Agenda

- Why pursue a Sustainable Flight Demonstrator?
- Acquisition Approach & Selected Partner
- Key Learnings
- X-66 Demonstrator
- NASA Roles
- Timeline
- Partnerships
- Outlook

Why invest in Sustainable Flight Demonstrator (SFD)?

- For decades Government, Industry, and Universities have been working advanced commercial aircraft concepts focused on lowering fuel burn & emissions

- To date, these configuration have not made it to market due to many factors including:
  - Competitive factors
  - Technical, integration, and manufacturing challenges
  - Large cost and risk of taking new configuration from design through certification

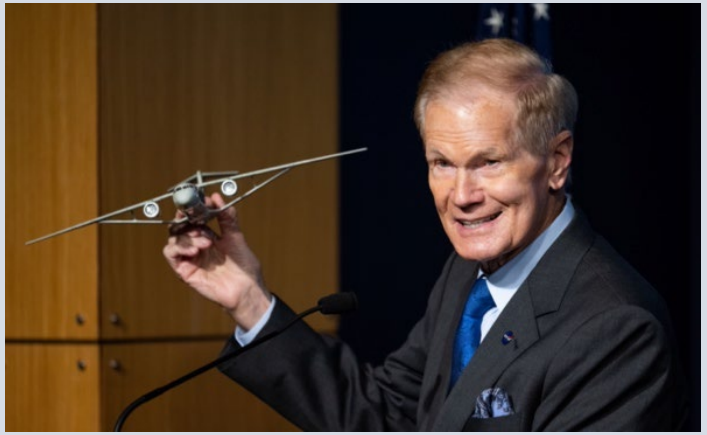
- NASA launched the SFD project to:
  - Partner with industry to retire as many technical & manufacturing risks as possible
  - Inform industry decisions associated with next generation single-aisle seat class product for 2030s entry into service
  - Maximize the potential to meet environmental goals articulated in the U.S. Aviation Climate Action Plan

Industry Partner selected through Competitive Proposals

- Selected Proposal was awarded a Funded Space Act Agreement (FSAA)
  - Boeing Company for their Transonic Truss Braced Wing (TTBW)
  - NASA providing $425M in direct payments in addition to significant labor and facility testing resources
  - Boeing providing an estimated $725M

- FSAA provides unique approach for project execution
  - Industry led; NASA supported
  - Industry defines requirements and project plan to maximize learning needed for future product consideration
  - Industry carries risk of cost overrun
  - Industry owns test aircraft
  - Industry has maximum Intellectual Property protection

Announcement of SFD Award



Bill Nelson, NASA Administrator

Todd Citron,
Boeing Chief Technology Officer

Bob Pearce, NASA Associate Admin.
for Aeronautics Research

Boeing / NASA Partnership

- Project success depends on a high level of collaboration
- Boeing/NASA project leadership teams are committed to collaborative approach to achieve the project goals
- Project Culture
  - X-66 designation pursued to rally team around research objectives
  - NASA engineers/technicians are assigned to work alongside Boeing counterparts on the Integrated Product Teams.
  - External communications are jointly coordinated
- Boeing/NASA Executive Board established to maintain engagement and resolve issues
  - Oct 30 Meeting: Definition of success and plan for response to major project threats
- NASA technical support commitment managed in a Technical Implementation Plan (TIP). Support will be adapted to meet project needs, within a level of effort defined in the award

Required Key Learnings

Sustainable Flight Demonstrator (SFD) Project

Performance, Stability & Control, and Handling Qualities

- CFD & Aero Performance Validation
- Flutter Characteristics
- Lateral Stability Characteristics
- Typical Flight Envelope Operability

Aeroelasticity

- Tool and Model Validation
- Static Loads Methods Validation

Structures

- Internal Loads Model Validation
- Primary Architecture & Joint Design Validation

Wing

- Thin Wing Integration
- Relevant High Lift Systems Architecture
- Fuel System Integration

Propulsion- Integration

- SAF Fuel System Compatibility
- Pylon Fail-safe Integration

Certification/Crashworthiness

- Strut Fail Safety Requirements
- High Wing/Truss Crush Loads

Advanced Air Transport Technology (AATT) Project

Wing

- Thin Wing Icing
- Deep Stall Risk
- High Lift System Architecture
- Scaling Effects

Acoustics

- Community Noise

Prior Work

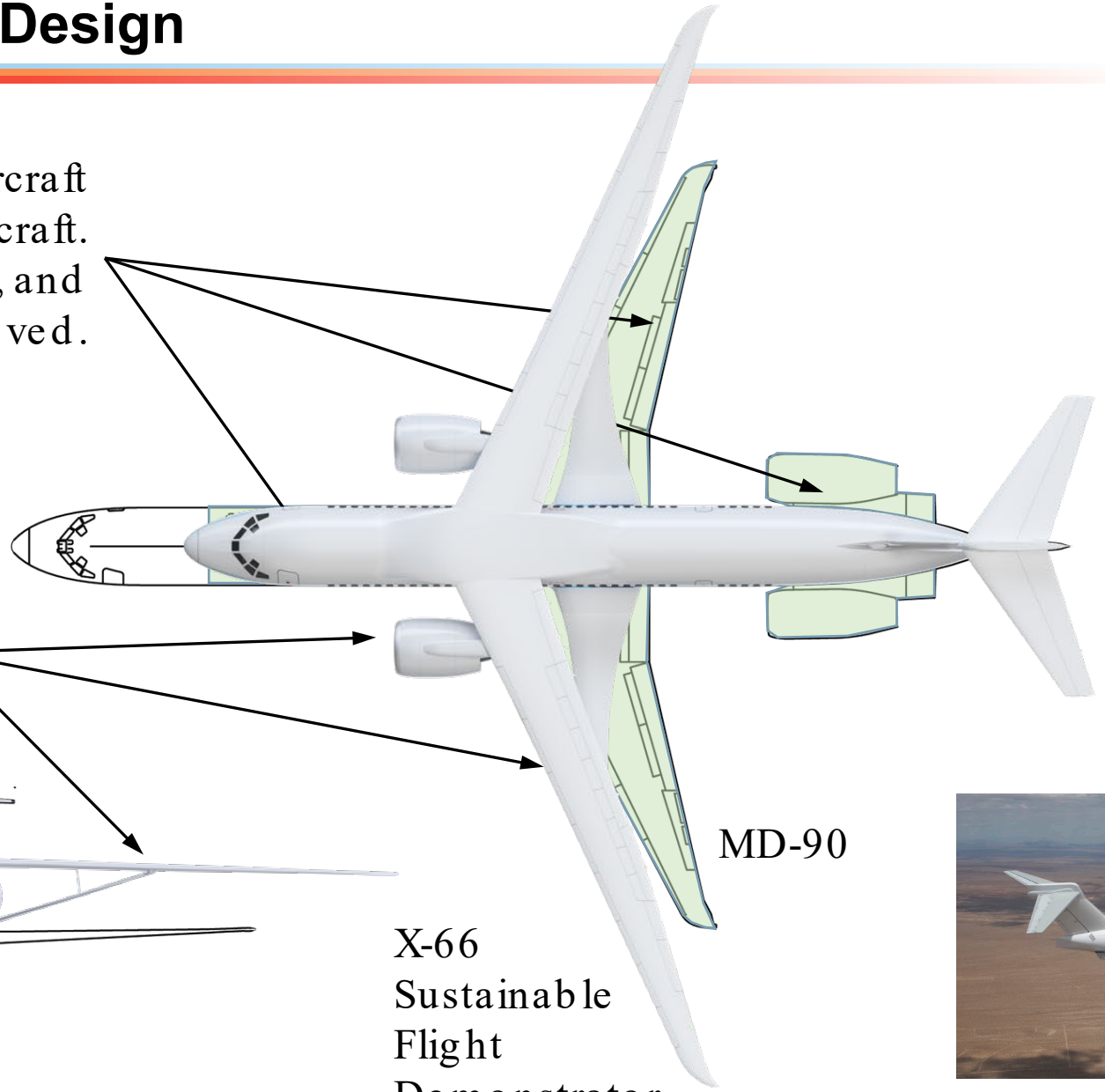
- Significant Architecture, Aerodynamic, Structures, and other studies that have advanced the configuration to its current state.

When combined with expected advancements in propulsion, materials and systems architecture, the TTBW configuration could reduce fuel consumption and emissions **up to 30%** relative to today's most efficient single-aisle airplanes.

X-66 SFD Demonstrator Design

Boeing will modify MD-90 aircraft into the SFD Demonstrator aircraft. Existing wings, aft engines, and fuselage sections will be removed.

SFD modification includes addition of Transonic Truss-Braced Wing and subsystems, modern, geared turbo-fan engines, and instrumentation.



X-66 Sustainable Flight Demonstrator

MD-90

MD-90 Donor aircraft ferried to Boeing Palmdale 8/19/23

NASA's Contributions to SFD

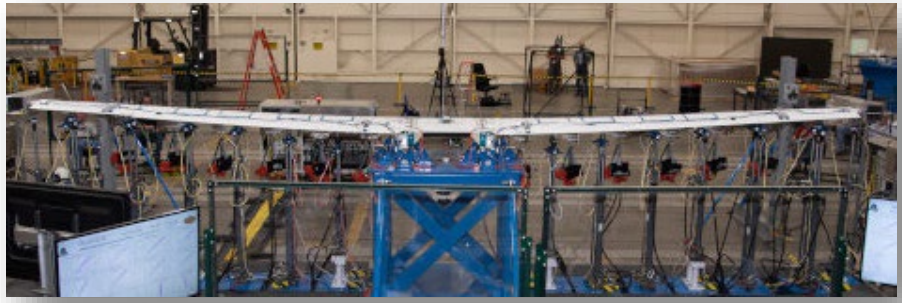
- Major testing support using NASA facilities/capabilities
  - High speed wind tunnel testing (LaRC)
  - Structural testing of wing components (AFRC)
  - Piloted simulation (AFRC)
  - Flight test operations (AFRC)
  - Acoustic testing (LaRC/AFRC)

- NASA technical support for Boeing-led Integrated Product Teams (IPTs)
  - Engineers
  - Mechanics/Technicians
  - Pilots
  - Program support

High Speed Wind Tunnel

Piloted Simulation

Structural Testing



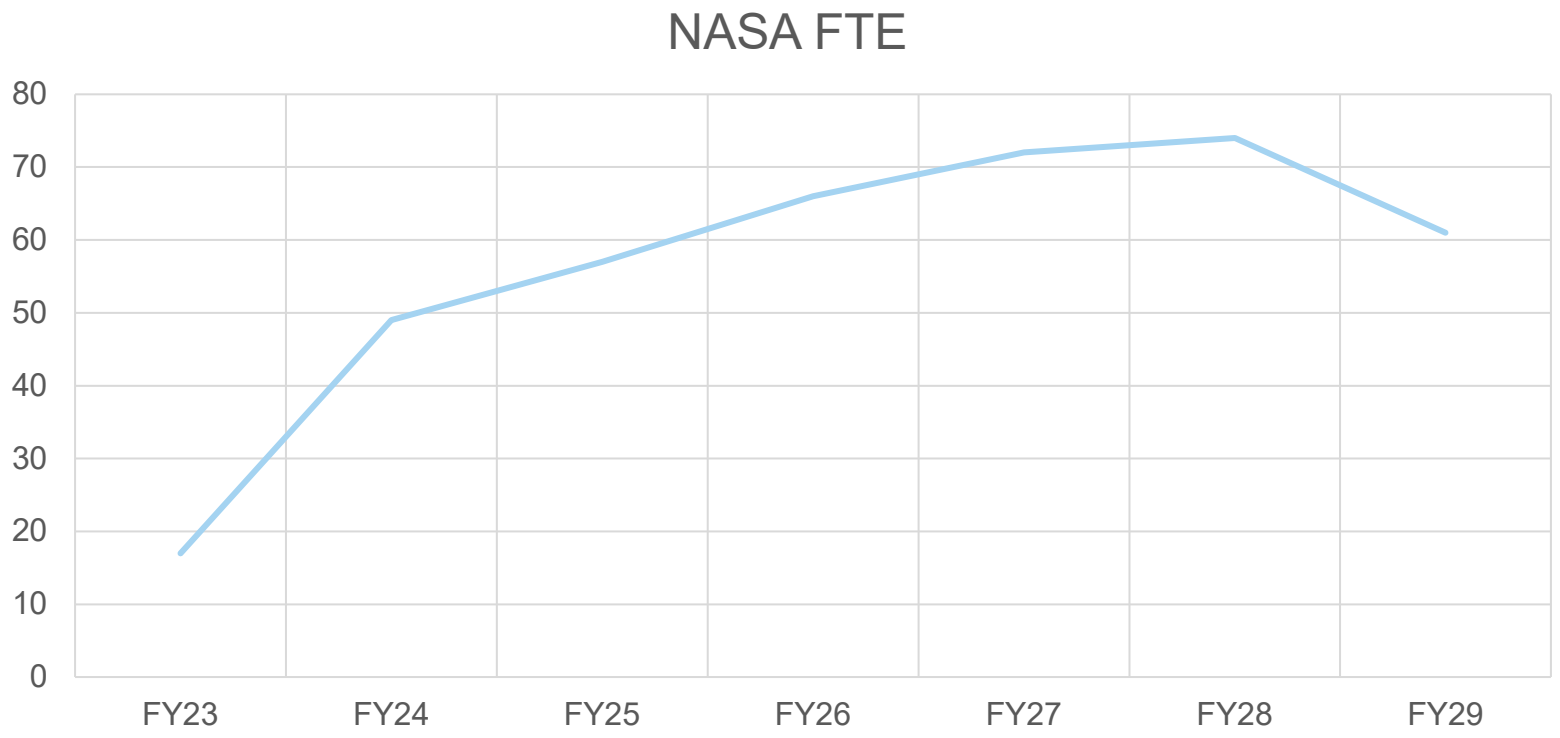
Chase Aircraft

Flight Test Facilities

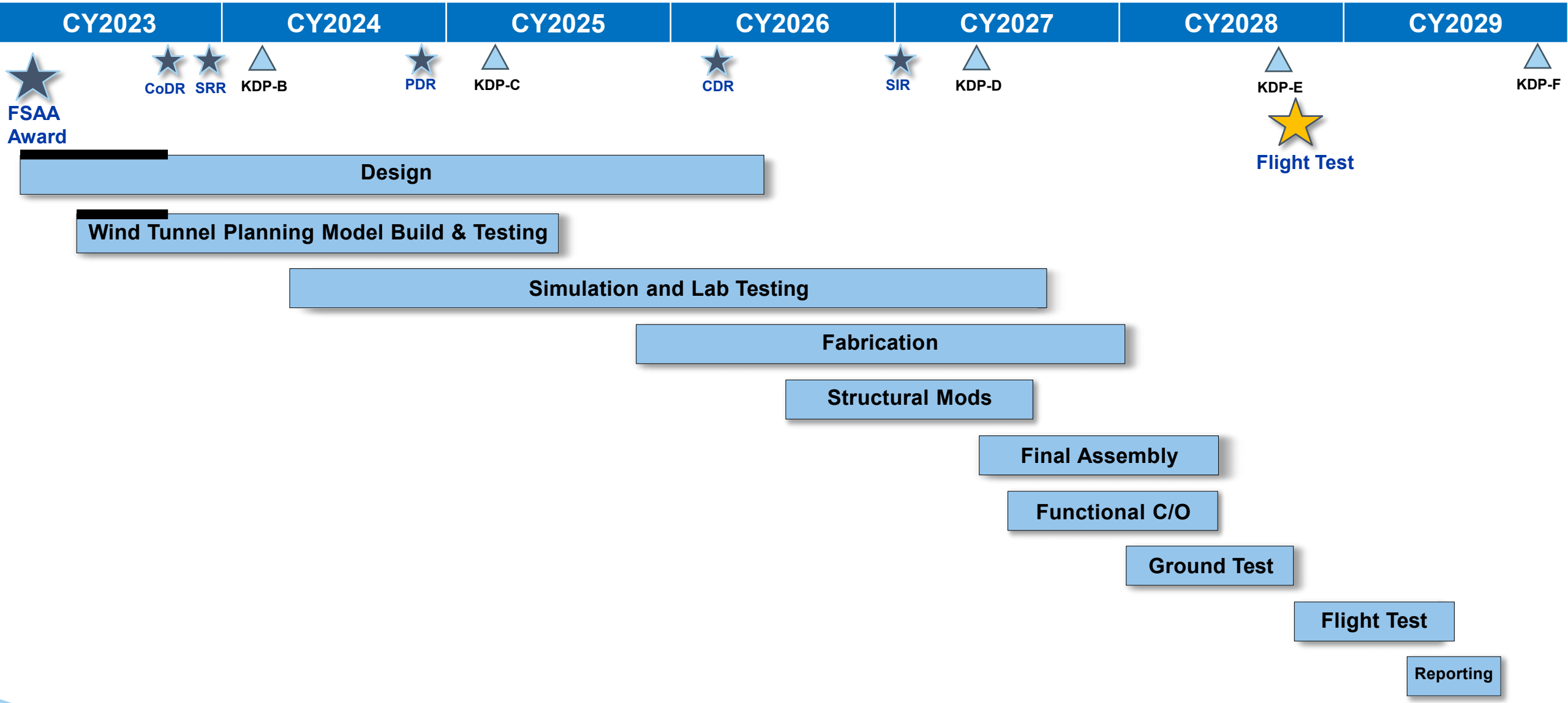
Acoustic Testing

X-66 SFD Staffing

- NASA staffing peaks during integration testing and initial flight test
  - Additional NASA staff contribute through operation of test facilities



SFD Project Schedule



CY: Calendar Year

FSAA Milestones

FSAA Milestone	Funding ($M)	FY23	FY24	FY25	FY26	FY27	FY28	FY29
Kickoff	$7.5	2/28/23						
Airworthiness Approach	$12.5	4/25/23 5/16/23						
Concept Design Review (CoDR)	$14.0	7/25/23 9/28/23						
System Requirement Review (SRR)	$17.75	10/24/23 12/7/23						
Aircraft Reactivation	$17.75	8/15/23 2/27/24						
Fuselage/Mod Preliminary Design Review	$17.75		5/28/24					
Wing/Strut Preliminary Design Review	$18.75		9/24/24					
Preliminary Design Review (PDR)	$23.5		11/26/24					
Begin Sim Design/Build	$23.5			2/25/25				
Wing/Strut Critical Design Review	$25.0			5/27/25				
Fuselage/Mod Critical Design Review	$25.0			8/25/25				
Propulsion Critical Design Review	$25.75			11/25/25				
Critical Design Review (CDR)	$27.25			2/24/26				
Mod Manufacturing Readiness Review	$27.25				6/30/26			
90% Engineering Readiness	$25.75				8/25/26			
System Integration Review (SIR)	$24.0				10/27/23			
MD-90 Fuselage High Blow Test	$24.0					2/23/27		
Final Aircraft Structural Assembly Complete	$24.0					4/27/27		
Final Ground Test Plan	$24.0					8/24/27		
Aircraft Power On	$3.75					10/26/27		
Aircraft Build Gauntlet Test	$3.75						3/28/28	
First Flight Readiness Review (FFRR)	$3.75						6/27/28	
Flight Line Gauntlet Test	$3.75						8/29/28	
First Flight	$1.5						9/26/28	
Envelope Expansion Complete	$1.5							2/27/29
Flight Test Complete	$1.5							6/26/29
Closeout Review	$0.5							8/28/29

Baseline
Planned
Accomplished
Payment Complete

Partnerships: SFD Airline Sustainability Coalition

Alaska
American
Delta
Southwest
United

- Boeing has established an SFD Airline Sustainability Coalition to advise their development efforts. The U.S. airlines will offer feedback through all phases of the program, including:
  - **Design:** Airline participants will share feedback on sustainable operations and airport compatibility.
  - **Simulation and lab testing:** Airline pilots will have a chance to experience the X-66A through a flight simulator and assess the vehicle's handling characteristics.
  - **Flight testing:** Airline operations and maintenance teams will assess the X-66A as modifications are made to the airplane. Flight testing is slated for 2028 and 2029 out of NASA's Armstrong Flight Research Center at Edwards Air Force Base.

Partnerships: Federal Aviation Administration

- While there is no formal partnership with the FAA, we believe that educating the FAA on the unique TTBW certification aspects will better prepare them for a potential commercial product launch later this decade.

- Sustainable Flight National Partnership (SFNP) Mission Office coordinated multiple SFD information sessions for FAA policy, certification, and environment technical staff
  - Intent is to periodically provide SFD updates and identify events for FAA to learn about unique TTBW safety considerations and Boeing/NASA approaches for establishing airworthiness

Project Outlook

Positive aspects

- TTBW design matured over 15 years
- High level of industry/government executive support
- Industry leadership team with broad commercial aircraft and freighter modification experience
- Excellent working relationships established at all levels
- Boeing & NASA facilities are available to meet project needs
- Jointly developed airworthiness approach
- Key learnings defined and tracked
- Process in place to adapt NASA workforce & work packages to changing needs of the project
- Donor aircraft restored to flight status
- Adequate resources available

Challenging aspects

- NASA budget uncertainty makes it difficult to ensure funding contributions according to the original agreement
- As expected, thin wing integration has required significant focus
- Manufacturing timeline relies on CFD and previous wind tunnel lessons to finalize design. Wind tunnel data will be used to validate design.
- Intellectual property protections have been established, with some reduction in efficiency

Questions?

Lessons Learned:

- Since ARMD had no previous FSAAs, development of the SFD acquisition and execution strategy relied on benchmarking and advice obtained through dozens of interviews.
- In an effort to share the SFD FSAA formulation experiences, numerous lessons learned sessions were held with the ARMD Chief Knowledge Officer, Ian Boyd.
- Ian is transforming those discussions and associated documents into an online FSAA Application Guide