RAYTHEON STARSHIP
Composite Wing & Fuselage Evaluation

Quick Look Report

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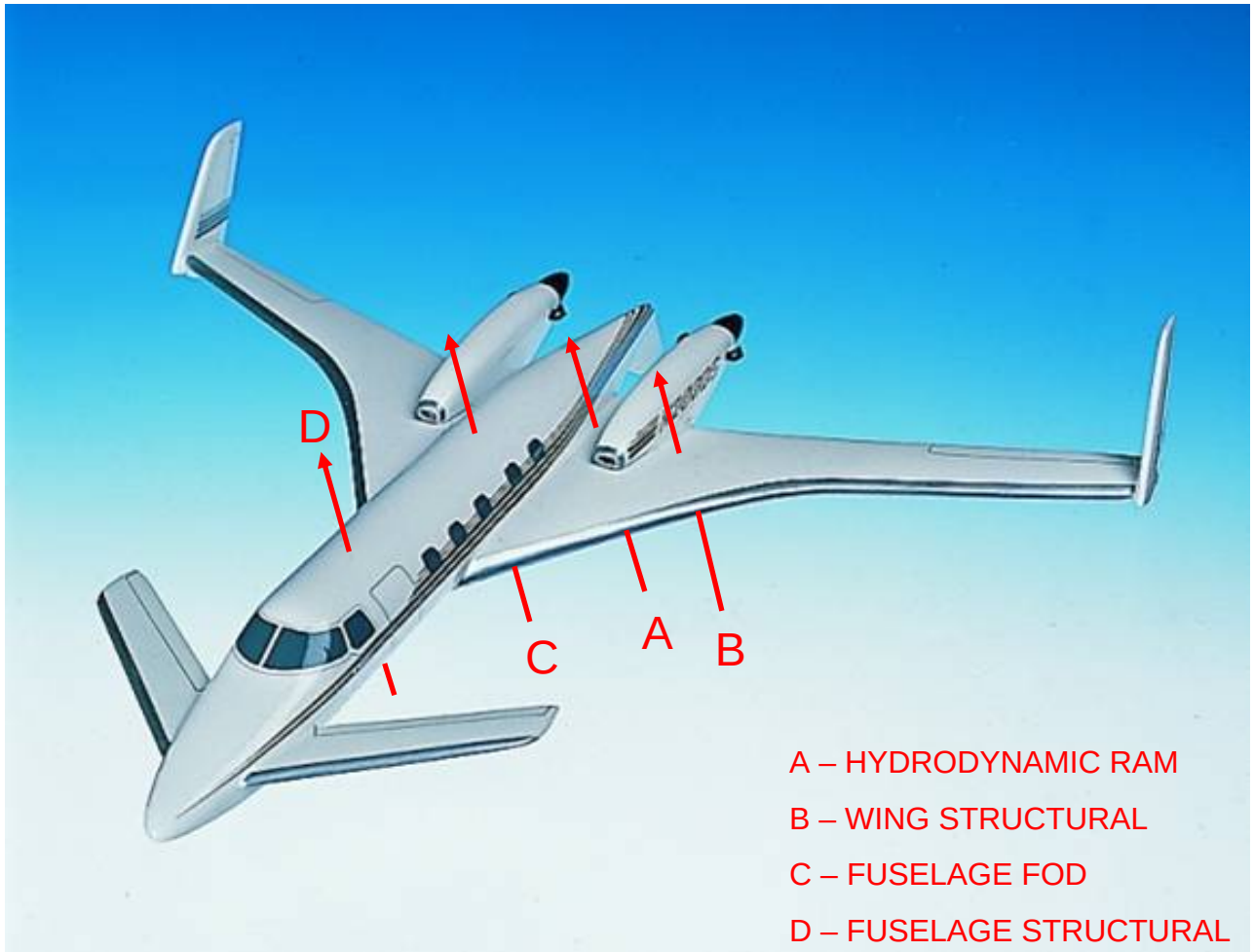
Composite Wing & Fuselage Evaluation
Test Issue/Objective

- Critical Issue
  - What is the expected outcome of threat impacts into honeycomb composite aircraft surfaces?
- Test Objective
  - Assess damage and safety-of-flight implications for threat impacts into honeycomb composite aircraft surfaces
- Approach
  - Select shotlines of interest to analysis partners
    - OSD interest in assessing magnitudes of damage generated by threat
  - Perform testing to gather previously unavailable data on the extent of damage caused by threat impacts on honeycomb composite aircraft surfaces
  - Decommissioned Starship aircraft used for testing
  - Transfer data to other organizations (OSD) for further analysis

Composite Wing & Fuselage Evaluation
Shot Lines Phase I



Composite Wing & Fuselage Evaluation
Shot Matrix Phase I

Shot	Threat	Location	Airflow	Loading
1 (D)	23mm HEI	Fuselage Forward	Yes	Pressurization 8 psi
2 (C)	F.O.D.	Fuselage Aft	No	No
3 (B)	23mm HEI	R. Wing (dry) O.B. of E.N.	Yes	Pre 1.2g Test 1.0g Post 1.4g
4 (A)	23mm HEI	R. Wing (wet) I.B. of E. N.	Yes	Pre 1.2g Test 1.0g Post TBD

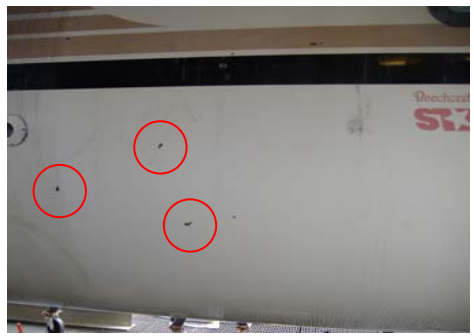
Composite Wing & Fuselage Evaluation
Test # 1 Results

- The projectile traveled approximately 25 feet from the gun to the test article lower surface. The projectile detonated immediately after it penetrated the fuselage.

Fragment impacts and blast overpressure shattered windshields.

Fragments penetrate belly of aircraft.

Nose cone and Base plate of round exit top of fuselage.



Composite Wing & Fuselage Evaluation
Test # 2 Results

- The projectile traveled 12.83 feet from the gun in .081225 seconds to the test article's lower surface. The projectile impacted the test article's structure, leaving a dime size indentation approximately 1/16 inch deep. The projectiles velocity at impact was 107.7 mph.

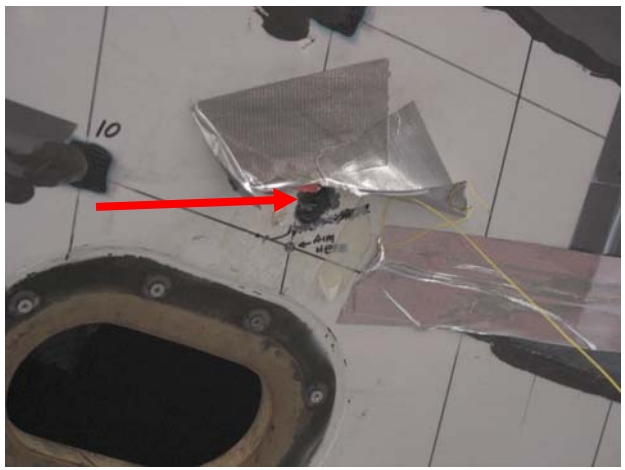
Pictures and NDI data TBD

Composite Wing & Fuselage Evaluation
Test # 3 Results

- The projectile traveled approximately 25 feet from the gun to the test article's lower surface. The projectile impacted the test article's structure, detonating several inches inside the wing.

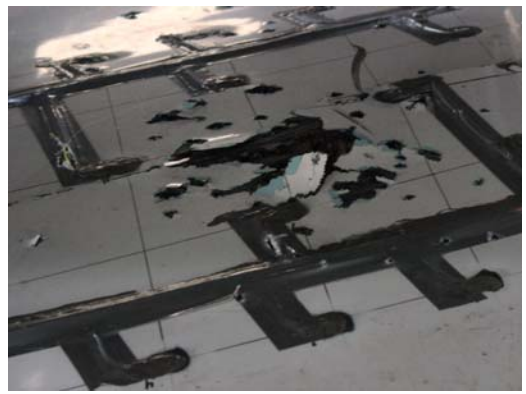
23mm HEI entrance hole.

Below wing looking up.



Exit pattern. Above wing looking aft.

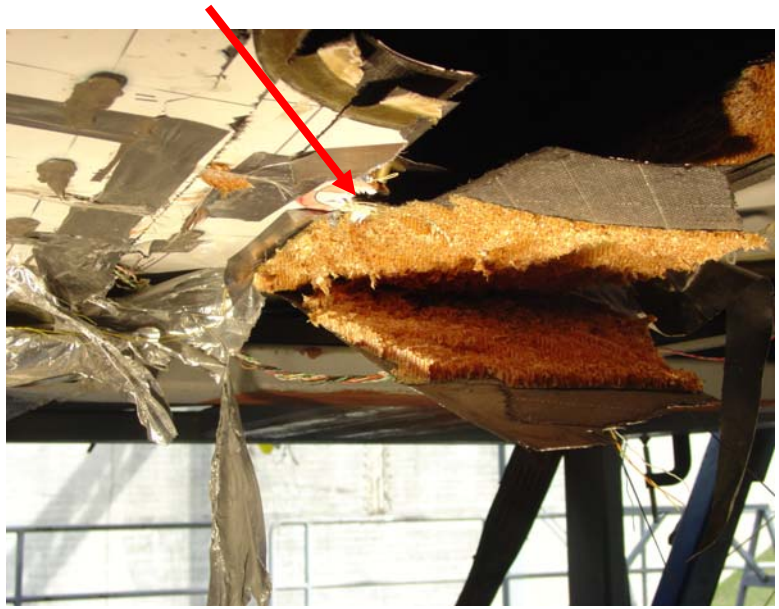
Exit pattern. Above wing looking forward.



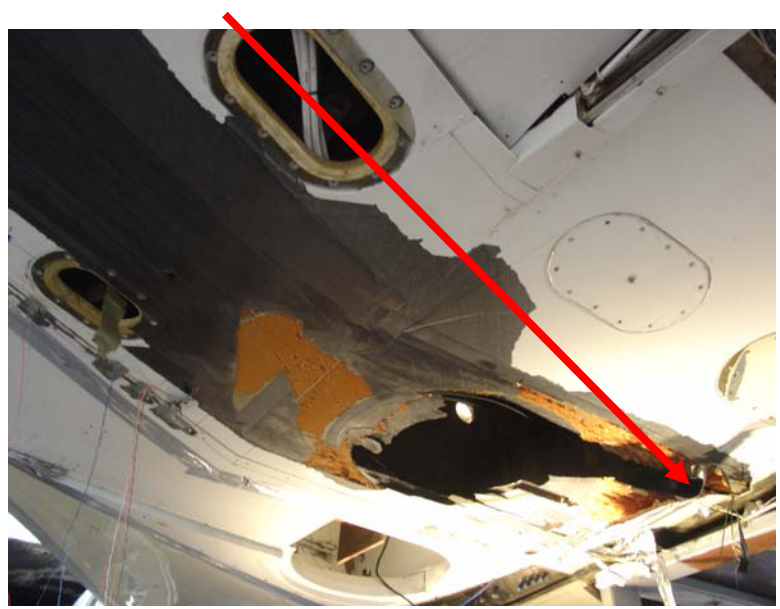
Composite Wing & Fuselage Evaluation Test # 4 Results (Bottom of Wing)

- The projectile traveled approximately 25 feet from the gun to the test article's lower surface. The projectile passed through the test article's structure detonating several inches inside the wing fuel tank filled with water.

Threat entrance point and explosion exit area. (aim point) Below looking aft.



Threat entrance point and explosion exit area. (aim point) Below looking forward.



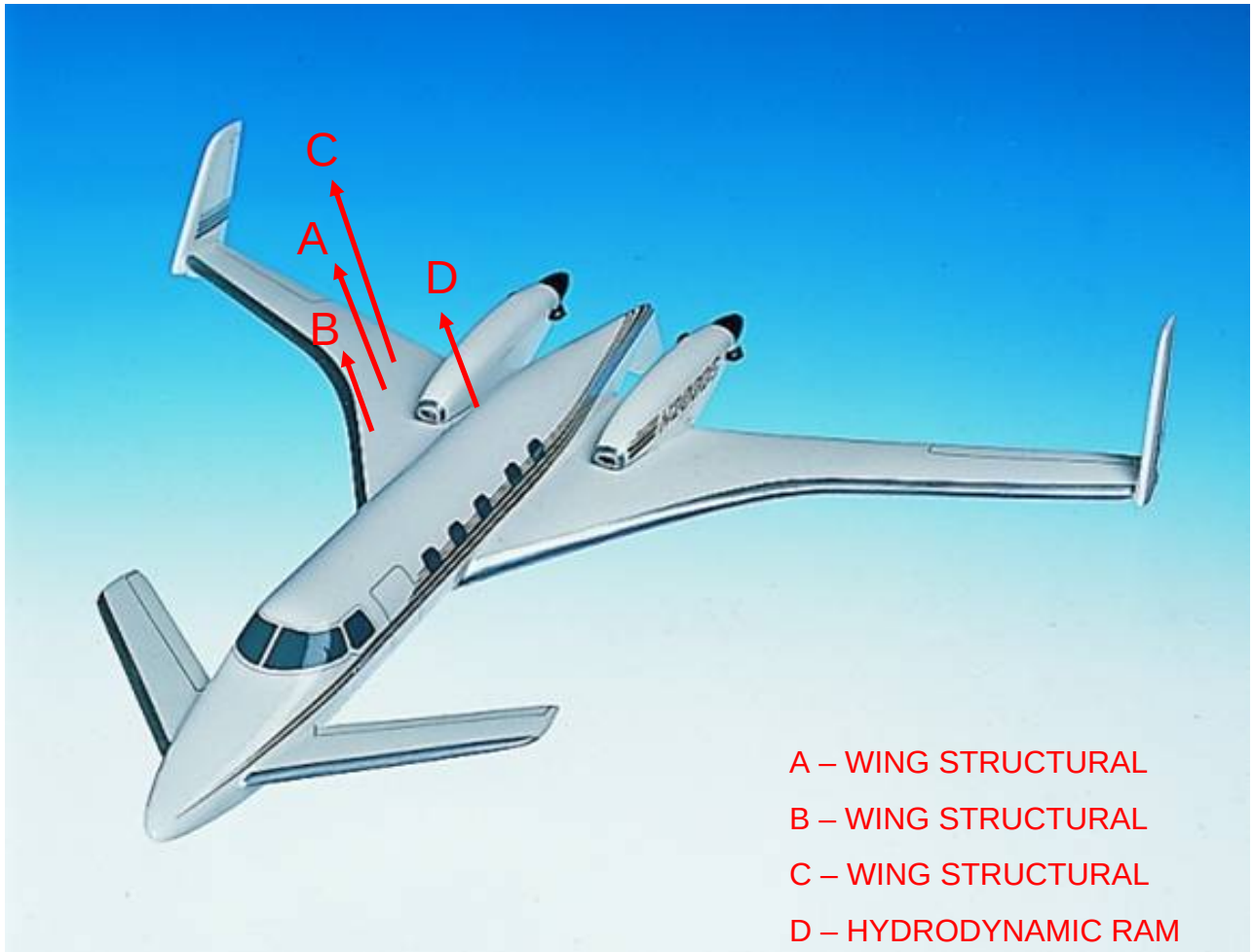
Composite Wing & Fuselage Evaluation Test # 4 Results (Above of Wing)

- The projectile traveled approximately 25 feet from the gun to the test article's lower surface. The projectile passed through the test article's structure detonating several inches inside the wing fuel tank filled with water.

Exit area and hydrodynamic ram structural damage. Above looking aft.

Exit area and hydrodynamic ram structural damage. Above looking forward.

Composite Wing & Fuselage Evaluation
Shot Lines Phase II

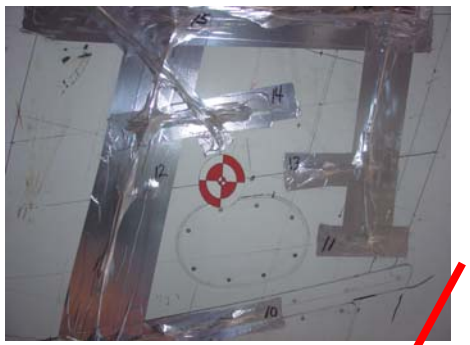


Composite Wing & Fuselage Evaluation
Shot Matrix Phase II

Shot	Threat	Location	Airflow	Loading
1 (A)	7.62mm AK-47x39	L. Wing (dry) O.B. & Fwd of E.N.	Yes	Pre 1.2g Test 1.0g Post 1.2g
2 (B)	5.56mm M-16	L. Wing (dry) O.B. & Fwd of E.N.	Yes	No
3 (C)	12.6mm	L. Wing (dry) O.B. of E.N.	Yes	No
4 (D)	12.7mm	L. Wing (wet) I.B. of E. N.	Yes	No

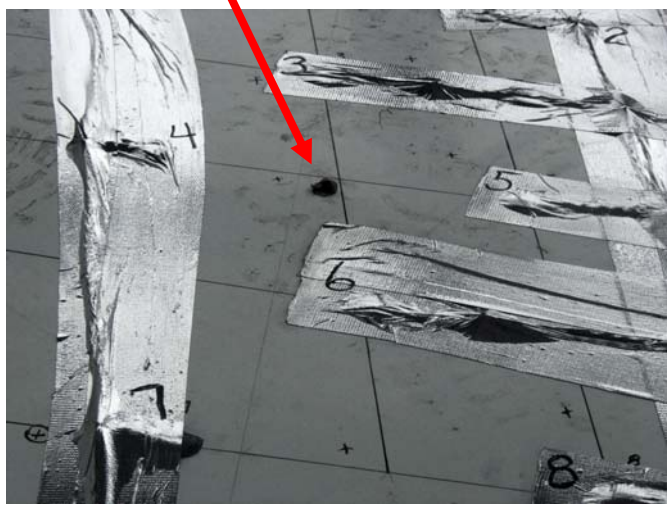
Composite Wing & Fuselage Evaluation
Test # 1 Phase II Results

- The projectile traveled approximately 25 feet from the gun to the test article's lower surface. The projectile penetrated the wing.



Instrumentation and entrance hole on bottom of wing.

Instrumentation and exit hole on top of wing.



Composite Wing & Fuselage Evaluation
Test # 2 Phase II Results

- The projectile traveled approximately 25 feet from the gun to the test article's lower surface. The projectile penetrated the wing.

Entrance hole

Exit hole

Composite Wing & Fuselage Evaluation
Test # 3 Phase II Results

- The projectile traveled approximately 25 feet from the gun to the test article's lower surface. The projectile passed through the test article's structure.

Threat entrance point.

(aim point) Below looking aft.

Threat exit point. (aim point)

Below looking forward.

Composite Wing & Fuselage Evaluation
Test # 4 Phase II Results

- The projectile traveled approximately 25 feet from the gun to the test article's lower surface. The projectile passed through the test article's fuel tank filled with water and exited out the top of the wing.

Threat entrance point. (aim point)

Below looking aft.

Threat exit area. (aim point) Above looking forward.

Preliminary Conclusions

- HEI threats will function upon impacting composite honeycomb structure. HEI functioning will result in overpressure and fragmentation damage to the surrounding structure. HEI hydrodynamic ram forces will massively damage composite structure surrounding a 80 gallon water filled fuel tank and bladder.

- Foreign Object Debris (FOD) can cause (waiting for NDI report) of the graphite/epoxy skin and permanent compression of the composite honeycomb core.

- Small caliber threats (5.56 – 12.7mm) will penetrate through a Nomex honeycomb core with graphite/epoxy skin wing structure with little surface delamination. 12.7mm threat will cause no hydrodynamic ram damage to a 80 gallon water filled fuel tank.

- 300 Kts airflow over ballisticaly damage composite honeycomb structure resulted in extremely minimal skin delamination.

- HEI and small caliber threats will cause minimal strength loss of Nomex honeycomb composite wing structure.

Lessons Learned

- The aircraft tested exceeded all expectations with respect to post test loading requirements despite the aircraft age, outdated manufacturing techniques and material properties.

- The composite evaluated was from a commercial business class aircraft. The fuselage had been through gutted prior to testing (no walls or flooring present).

- Future testing, of composites aircraft designed and manufactured to military specifications, will be needed to determine the level of ballistic protection composites can provide.