Conference Paper

Estimating Alternatives for Joint Future Theater Lift (JFTL)

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The JFTL Technology Study (JTS) analyzed the comparative cost-effectiveness and risk of several alternative cargo lifter designs

- The JTS alternatives address capability shortfalls identified in the JFTL Initial Capabilities Document (ICD); an essential capability shortfall being the delivery of a combat-configured medium weight armored vehicle (up to 36 tons) into austere, short, unimproved landing areas without ground handling equipment

- This presentation is meant to familiarize the audience with the background to the study, the tools and methods used in developing the cost estimates and an overview of the type of analysis the cost working group developed

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The study explored theater lift for the beyond 2020 timeframe

- The existing inventory of transport aircraft are limited in their ability to transport heavy cargo (greater than 25 tons) to austere unimproved landing zones where military forces routinely operate

- Key study milestones include:
  - The 2008/2009 Army-Air Force Warfighter Talks merged the Army's Joint Heavy Lift (JHL) ICD with Air Force's Joint Future Theater Airlift Capability Assessment (JFTACA) requirements into a single ICD and directed a Joint Analysis of Alternatives (AoA)

    The Air Force was given administrative lead for intra theater airlift of medium-weight armored vehicles; Army lead for Mounted Vertical Maneuver (MVM) Concept of Operations (CONOPS)
  - In August 2010, the study changed from Joint AoA to Joint Technology Study because there was no Material Development Decision by the Air Force
  - In November 2010, the Air Force Requirements Oversight Council (AFROC) approved the JFTL Technology Study Plan
  - In April 2012, the results were briefed to the Senior Review Group (SRG) and General Officer Steering Group (GOSG) in preparation for a July 2012 Final Report and AFROC

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The JFTL Technology Study was the first Technology Study conducted to the rigor of an AoA

- And like a traditional AoA this study was overseen by the cognizant cost agencies
- Office of Aerospace Studies (OAS)
  - Representation at team meetings with additional oversight during milestone reviews
- Air Force Cost Analysis Agency (AFCAA)
  - Reviewed methodology, interim and final results
- Deputy Assistant Secretary of the Army for Cost & Economics (DASA / CE)
  - Reviewed methodology, interim and final results
  - Focused on the analysis method for the Tiltrotor
- Office of the Secretary of Defense Cost Assessment and Program Evaluation (OSD CAPE)
  - Provided oversight at milestone reviews (Senior Review Group meetings)

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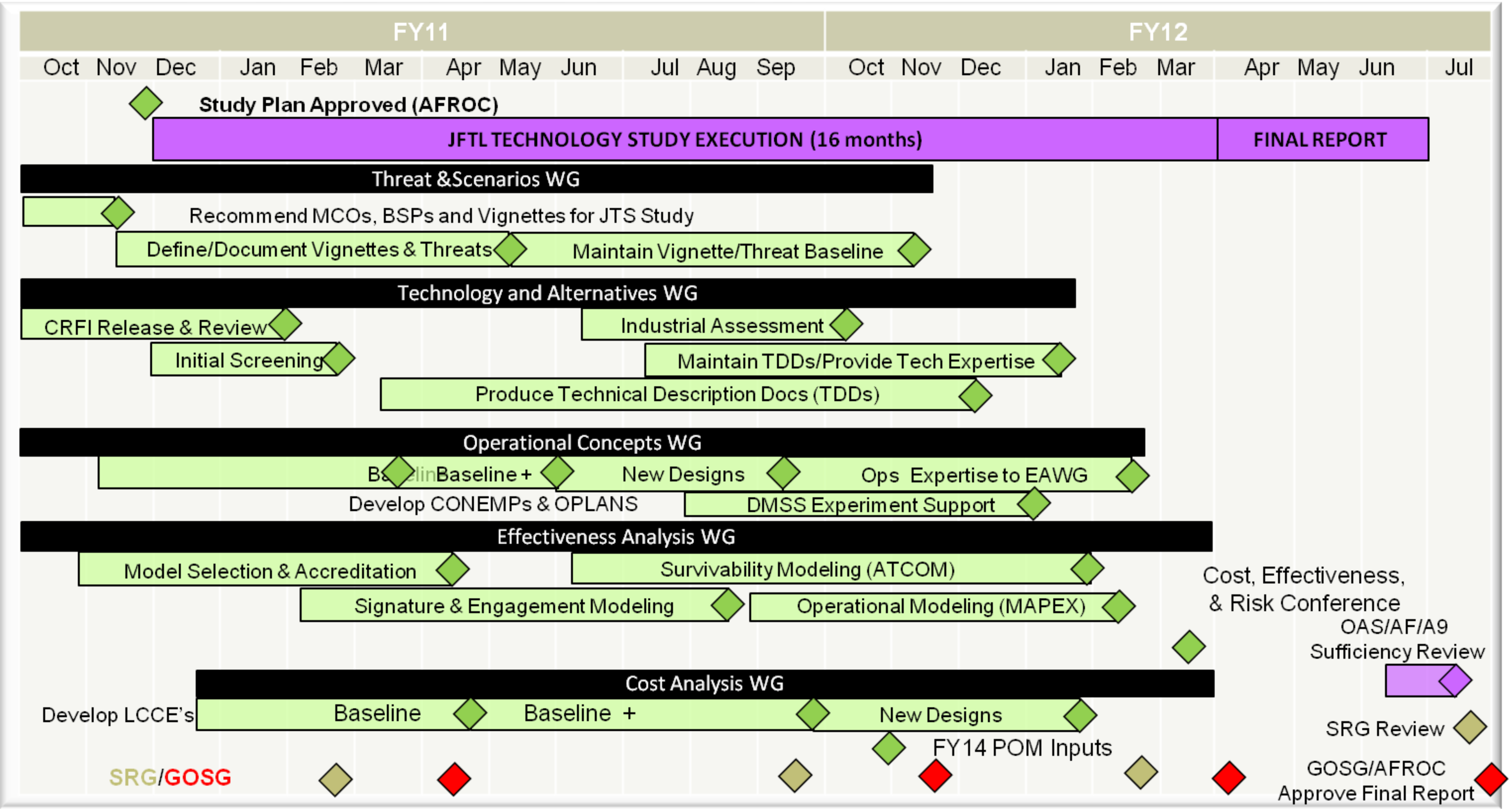
The study schedule began in late 2010 and runs into summer 2012



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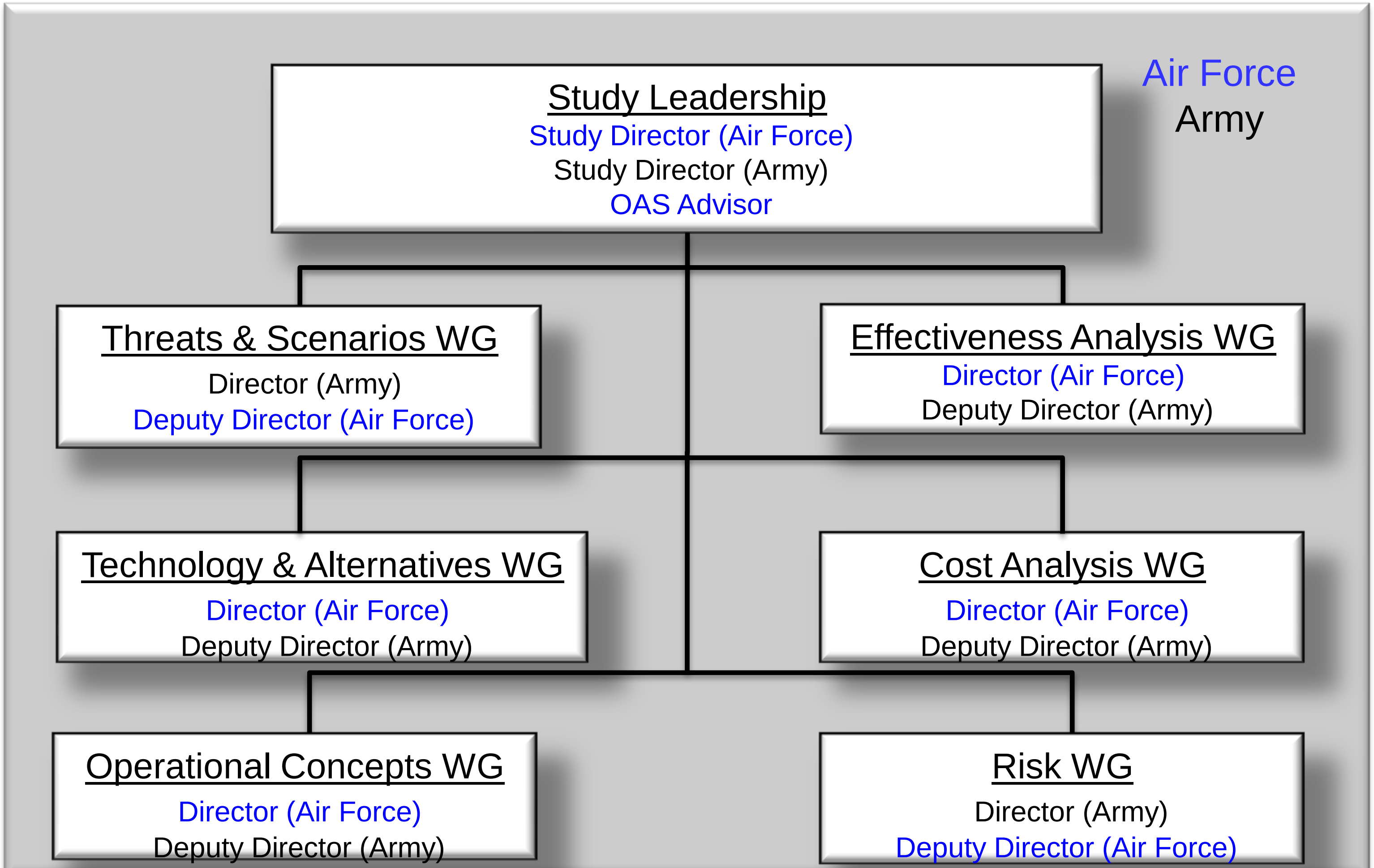
The Air Force led the study with considerable support from the Army



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The JFTL Technology Study considered six Alternatives besides the baseline

- For purposes of comparison the baseline is comprised of today's fixed wing strategic and tactical cargo lifters and rotary wing cargo lifter
  - C-17A Globemaster III
  - C-130J Hercules
  - CH-47F Chinook

Note: Aircraft photographed are not shown to scale

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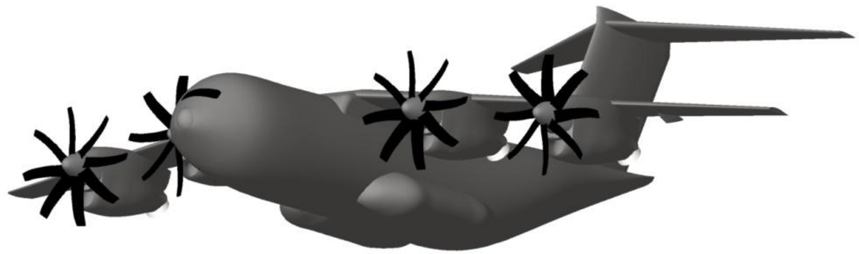
The first two alternatives are based on existing aircraft

- The Conventional Turbo Prop (CTP)
- The Conventional Turbo Fan (CTF)



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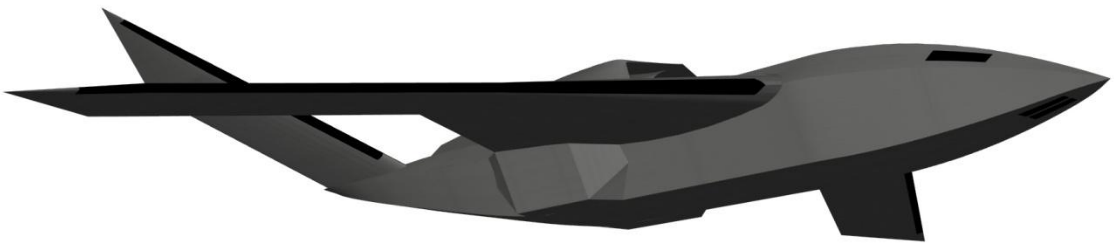
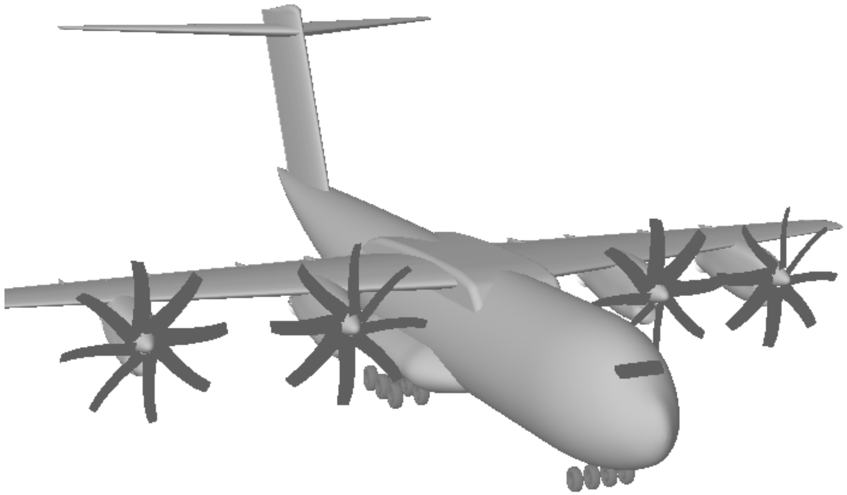
The next two alternatives are new design fixed wing aircraft

- The Shaped Planform Turbo Fan (SPTF)
- The STOL Turbo Prop (STP)





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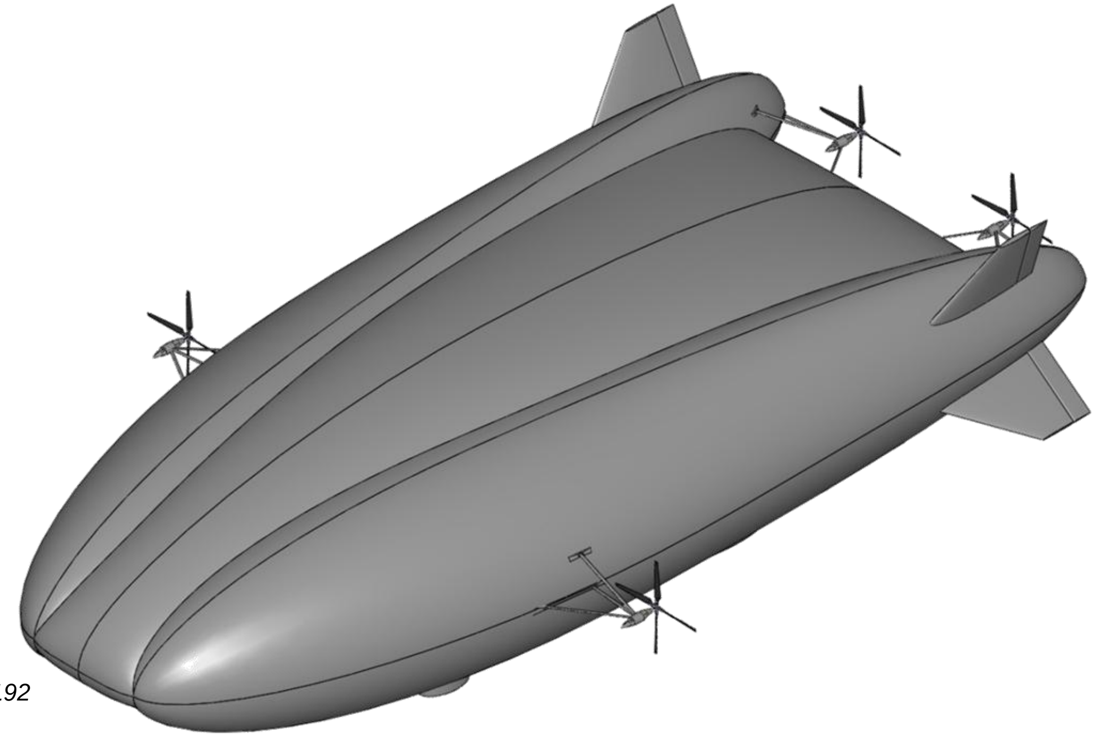
The final two designs were also new designs but not fixed wing aircraft

- The Tiltrotor (TR)
- The Hybrid Airship (HA)



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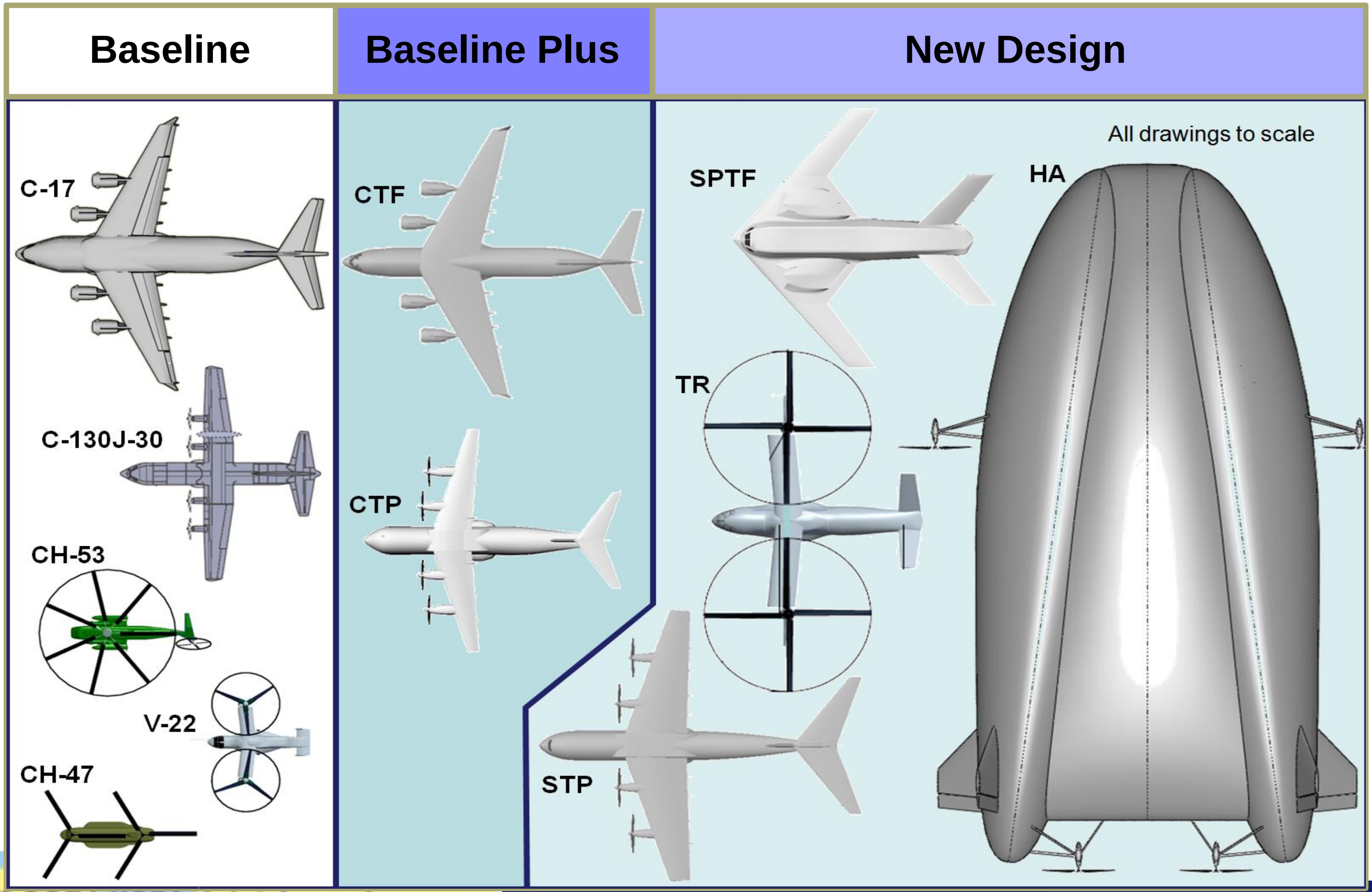
The following chart shows the JFTL in relative size to each other and existing aircraft



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The table below describes the Mission Areas and Capability Gaps in detail

Mission Area	Description of Capability Gap
Intratheater Operational Maneuver (IOM)	Inability to: - Operate into austere, short, unimproved landing areas - Perform operational maneuver with medium weight armored vehicles and personnel - Reposition medium weight armored vehicles and personnel
Operational Maneuver from Strategic Distances (OMSD)	Inability to: - Transport forces over strategic/operational distances to points of need / effect bypassing PODs - Operate into austere, short, unimproved landing areas - Minimize RSOI
Distributed Maneuver Support and Sustainment (DMSS)	Inability to: - Operate into austere, unimproved landing areas - Operate into landing areas with limited infrastructure - Conduct precision air delivery over strategic and operational distances with required velocity
Joint Forcible Entry Operations (JFEO)	Inability to: - Transport forces over strategic/operational distances to points of need/effect bypassing PODs - Operate into austere, short, unimproved landing areas - Minimize Reception, Staging, Onward Movement and Integration (RSOI)

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Like a traditional AoA the Study established ground rules and assumptions

- Base year is FY2012
- A Notional Acquisition Schedule was developed for the purpose of phasing costs
- Life Cycle includes Engineering & Manufacturing Development(EMD), Production, Operations and Support (O&S), Military Construction (MILCON) and Disposal
- Life cycle includes 30 years of O&S for each aircraft
- O&S cost for new aircraft begins one year prior to the first delivery
- O&S estimates are based on standard peacetime operations
- MILCON requirements are generically addressed (no specific base or building information) as necessary for each alternative based on quantity and size of new aircraft
- LCCEs include all applicable costs for budgeting, such as engineering change orders (ECOs), spares, data, etc.

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The study used the in-house developed Aircraft Conceptual Design Cost Model (ACDC) as the primary estimation tool

- Excel-based tool started in 2003 in collaborative effort with RAND and AFCAA
- Utilizes methodologies developed from a variety of sources including Aeronautical Systems Center (ASC) studies, RAND, AFCAA and other sources and factors based on Institute for Defense Analyses (IDA) estimates for Low Observability (stealth) impacts
- Reviewed with and verified by OSD/Cost Analysis Program Evaluation (CAPE), AFCAA, Aeronautical System Center Financial Management Center (ASC/FMC) and the Office of Aerospace Studies (OAS)
- Designed for Alternatives comparison
- ACDC successfully used in several AoAs

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A critical element in developing defendable LCCE was validating the model's CERs and outputs

- There were three primary approaches for validating the model
- First, validate each of the primary CER used to estimate the major WBS components
- Second, compare the output of the model to historical actual cost as a cross check
- Third, calibrate the model (established for fixed wing aircraft) to the Tiltrotor using the V-22 Osprey tiltrotor as an analogy

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The method for crosschecking the development estimates was most often comparison to historical program costs

Element	Estimation Method	Author	Heritage	Crosscheck
Non Recurring Airframe	Parametric	RAND	2001	Historical Programs
Non Recurring Engine	Parametric	RAND	2002	Historical Programs
Avionics - Hardware	Parametric	ASC	2007	Historical Programs
Avionics - Software	Parametric	SEER-SEM	2011	PRICE True Planning
Tooling	Parametric	RAND	1991	Historical Programs
Recurring Development Costs	Parametric	Learning Curve Slope		Historical Programs
SEPM, Spares, OGC	Factor	ASC adjusted Blair	2000	Historical Programs
Contractor Test	Factor	Murphey	2005	Historical Programs

(1) ASC – Aeronautical Systems Center internal analysis
(2) SEPM – System Engineering / Program Management
(3) OGC – Other Government Costs
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The same holds true for Production, Operations & Support (O&S), Military Construction (MILCON) and Disposal

Element	Estimation Method	Author	Heritage	Crosscheck
Production Airframe	Parametric	RAND	2001	Historical Programs
Production Engine	Parametric	RAND	2001	Historical Programs
Production Avionics	Analogy	ASC	2011	Historical Programs
SEPM	Factor	Blair Study	2005	Historical Programs
Spares	Factor	Blair Study	2005	Historical Programs
Data	Factor	Blair Study	2005	Historical Programs
Training	Factor	Blair Study	2005	Historical Programs
Support Equipment	Factor	Blair Study	2005	Historical Programs
OGC	Factor	Blair Study	2005	Historical Programs
ICS	Factor	Blair Study	2005	Historical Programs
O&S	Parametric	ASC/XRE	2005	Historical Programs
MILCON	Parametric	ASC/XRE	2011	Historical Programs
Disposal	Parametric	ASC/XRE	2011	Historical Programs

(1) SEPM – System Engineering / Program Management
(2) OGC – Other Government Costs
(3) ICS – Interim Contractor Costs
(4) O&S – Operations and Support
(5) MILCON – Military Construction
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As a 'sanity check' estimates were compared to historical actual cost for other aircraft

- Used RAND developed 'Ouija Boards' which plot Empty Weight (EW) by actual cost in a logarithmic scale
- For the EMD estimates the data plotted is actual EMD cost and EW of existing systems and estimated EMD for the JFTL alternatives at the 50^{th} % confidence
- The model output for the B-2 and C-17 aircraft were shown to have a good fit compared to actual cost
- Similarly the AUPC estimates for the first 100 aircraft was compared to historical actual cost
- Data plotted on the Production Ouija Board chart is actual AUPC and EW of existing systems and estimated AUPC for the JFTL alternatives
- When the model estimate for the first 100 B-2 bombers and 100 C-17 aircraft are plotted, the estimates are below the actual cost

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The one area where the Technology Study deviated from the standards of an AoA was in the detail of the O&S estimate

- Typically for an AoA the O&S cost would have been estimated by Cost Analysis Improvement Group (CAIG) category
- Given the difficulty of estimating at that level especially for four completely new designs with limited resources on the Cost Analysis Working Group, the decision was made to develop a top level CER for O&S

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The CER for O&S in the model was developed specifically from cargo aircraft actual cost

- Developed by a regression analysis using JMP® software from SAS
- Data source was the Air Force Total Ownership Cost (AFTOC) database data on all cargo and tanker aircraft in the Air Force inventory today
- Three main factors were = Total Aircraft Inventory (TAI), average flying hours per aircraft (FH), and empty weight (EW)
- The CER is -704,478,318 + 6,895,737 x TAI + 1,209,399 x FH/TAI + 1,652 x EW
- The CER equation has an R-Square = 84.55%
- As a sanity check for O&S a similar "Ouija board" chart was developed to show the estimated O&S per FH by EW compared to O&S per FH by EW for existing aircraft

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After validating the CERs and crosschecking the outputs against actual cost, we calibrated the model for the Tiltrotor (TR)

- Our assumption is that the largely weight based CERs will under estimate the cost of a TR
- The TR configuration presents unique cost estimating challenges
- Existing fixed/rotary wing cost models will not capture complexities inherent in TR alternative
- The goal is to determine appropriate methodologies to estimate the TR development costs using ACDC
- As the V-22 has a similar configuration to the TR alternative, the ACDC was calibrated to historical V-22 actual cost data

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The calibration followed a six step process

1. Collect the data
   – Historical cost data from V-22 EMD program
   – V-22 technical parameters required to populate cost model inputs (EW, aircraft speed, avionics weight, etc.)

2. Normalize the data for inflation
   – Convert TY$ reported in CCDR to BY12 by cost element

3. Perform cost analysis using ACDC model with V-22 technical inputs

4. Compare results of Step 2 and Step 3

5. Determine appropriate scaling/complexity factors as needed to calibrate model

6. Perform cost analysis using calibrated ACDC model with Tiltrotor technical inputs as reported in the Technical Description Document

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As is typical there were some issues with the cost data

- The Presidential Budget documents (PB docs), Selected Acquisition Reports (SAR), and Bell Boeing Contractor Cost Data Reports (CCDR) were the primary data sources

Issue	Mitigation
▸ Costs reported in Then Year dollars (TY$)	▸ All reported costs escalated to Base Year 2012 (BY12) using OSD rates
▸ Government costs such as Government Furnished Equipment (GFE) and Program Support not captured in Contractor Cost Data Reports (CCDR)	▸ Used Presidential Budget (PB) documents which reflected more cost that was in the CCDR ▸ PB docs reported government and contractor costs separately
▸ Unable to locate PB docs for FY85-87	▸ Used Selected Acquisition Reports (SAR) reports in place of PB docs which do not report government costs separate from the prime contractor's costs ▸ Assumed the total amount in the SAR above the CCDR was government costs
▸ Unable to locate Final CCDR for Period of Performance (PoP) FY85-91	▸ Used interim report from 1988 instead

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The final step taken after total EMD cost in BY12 had been obtained for contractor and government was to normalize the data further

- Contractor profit and indirect costs such as overheard are reported separately in the CCDR but are not reported separately in ACDC
- The indirect costs were allocated on a percentage basis
- The CCDR reflected 28% of the total cost as indirect costs
- So an additional 28% was added to each Work Breakdown Structure (WBS) element for comparison to the ACDC output
- In additional there were minor WBS mapping adjustments that had to be made

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If ACDC with its existing CERs was used as is, V-22 development would have been under estimated by half

- Non Recurring Engineering (NRE) costs were not the issue
- The model was spot on for NRE costs
- Recurring Engineering, SEPM, Contractor Test and Other Government Costs (OGC) were, however, under estimated

Element	Actual Cost BY12$M	Model Output Pre-Calibration
Total Development	**11,725**	**6,937**
– Contractor	**10,147**	**6,388**
Prime Equipment	5,758	4,465
- Non Recurring (Airframe, Engine, Avionics)	3,830	3,854
- Recurring	1,928	611
SEPM	1,630	98
Contractor Test	2,579	1,425
– OGC	**1,578**	**549**

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As a result of the analysis several complexity factors were added prior to using the JFTL Tiltrotor values for the CER variables

- A complexity factor was added to the Airframe CER as well as adjustment factors for SEPM, and Contractor Test
- An interesting finding is that a significant portion of the V-22 software was GFE and reflected in the OGC line, therefore no adjustment was made to the original OGC factor in the model
- Tiltrotor software was estimate as a separate item fed into the model as a throughput
- Note the final result was still a point estimate from the model
- Uncertainty was modeled using Crystal Ball in the model as well with risk ranges and correlation for the individual CER

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All of this analysis validated the cost model, however, there are also life cycle costs outside of the phases the model estimates

- First, the cost model is only designed to estimate cost post Milestone B, that is after the Engineering, Manufacturing & Development phase of the life cycle
- Several of the designs had Critical Technology Elements (CTE) which were below the DoD mandated Technical Readiness Level (TRL) of 6
- This CTE would have to be brought up to a TRL of 6 in the pre Milestone B Technology Development Phase
- The Cost Analysis Working Group (CAWG) relied on estimates provided by the Air Force Research Laboratory for the cost of the effort required to elevate CTE to TRL 6
- The CAWG re-used the Army's Aeroflightdynamics Directorate's estimate from the Joint Heavy Lift (JHL) Study for the Tiltrotor's pre Milestone B costs
- Additional cost was also added for pre Milestone B government planning costs
  - These costs were based on historical program planning actual cost from Air Force Material Command (AFMC) Capabilities and Requirements Integration Directorate (XR)

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Validating the cost model set the scene for the work on the various cost analysis products

- First, the CAWG was tasked with developing an estimate for Air Mobility Command (AMC) to consider JFTL for its FY2014 POM
- Second, the CAWG developed LCCE with the quantity of aircraft set at 100, 150, 200 and 250
- Third, the CAWG developed an estimate of the operational cost of conducting Distributed Maneuver Support and Sustainment (DMSS) for Afghanistan for one month assuming various JFTL aircraft vice the current approach
- Fourth, the CAWG developed LCCE tied to Effectiveness for the purpose of cost and effective comparison

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The near term investment option for was developed October 2014

- Used the Shaped Planform Turbo Fan (SPTF) as the representative JFTL alternative for the purpose of costing
- The SPTF was chosen because the SPTF represents a median solution from a project cost perspective sufficient for an FY14 POM wedge for future JFTL development activities
- The estimate was time phased with an option for Milestone B in 2020 and an option for Milestone B in 2025

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The parametric quantities were a solution to the question of determining the quantity of aircraft

- There was interest in unit pricing
  - Some team members felt the DoD would base decisions on lowest per unit price
  - Led to considerable discussion how many aircraft should be assumed per given alternative for production and O&S cost
- The CAWG's solution was to estimate LCC for range of quantities for each alternative
  - Representative quantities were 100, 150, 200 and 250 aircraft
- Resulted in four LCCE for each alternative at considerable effort by the CAWG
- Quantities were not tied to mission effectiveness, however, and therefore not part of OSD CAPE decision process

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The third cost analysis did not include Tech Maturation, development, or production costs

- Costs captured consisted of three elements: fuel used, personnel costs, and air/ground vehicle O&S
- Focused on the operational cost only for one month's operation
- Quantities arrived at as part of the Army's Sustainment Battle Laboratory (SBL) at Fort Lee, Virginia analysis for JFTL
  - Identified total crews and fuel used for each JFTL alternative
- The primary goal was to show the operational and logistical benefits of increasing reliance on aerial sustainment vice reliance on ground sustainment
- Results showed that aerial sustainment was significantly more expensive than ground-based sustainment
- Baseline assets able to sustain forces in theater and the baseline was the lowest cost option

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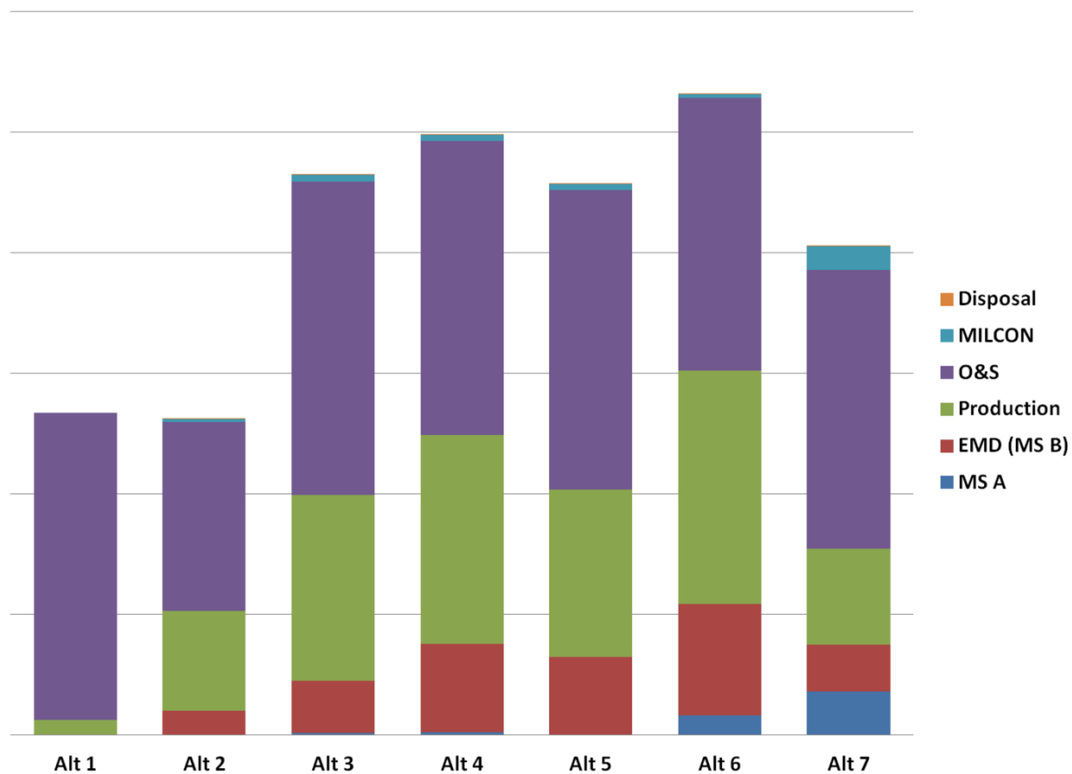
The final analysis was a LCCE tied to effectiveness

- The Alternatives LCCE was tied to Alternative specific quantities of aircraft
- Lower cost alternatives were also less effective
- Higher cost alternatives were also more effective

Risk Adjusted Mean Confidence Level
BY2012 $M



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