ULLAGE PROTECTION OWNERSHIP COST FOR KC-130J: EXPLOSION SUPPRESSANT FOAM (ESF) VS. ON-BOARD INERT GAS GENERATION SYSTEM (OBIGGS)

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ABSTRACT

The U.S. Navy is procuring KC-130J aircraft concurrent with USAF procurements of C-130J aircraft. These platforms are categorized as commercial-off-the-shelf (COTS) procurements in that they are derivatives of legacy C-130 model aircraft in use by the Navy and Air Force today. This means that to the extent practical existing qualified systems on the legacy aircraft have been carried over to the newer C-130J/KC-130J models. These systems include the passive ullage fire/explosion protection system employed in the majority of fuel tanks on the legacy C-130 aircraft. This passive system provides ballistic vulnerable area reduction and consists of many individual pieces of explosion suppressant foam (ESF) per MIL-F-87260. On the KC-130J aircraft, the total weight of all pieces installed in the main, auxiliary and external tanks is 1,666 lbs. On C-130J, this weight is 1,192 lbs as ESF is installed only in the main and auxiliary tanks.

Ullage fire/explosion protection has recently been the focus of extensive investigation since the TWA 800 tragedy. Two aviation rulemaking advisory committee (ARAC) efforts have been conducted to explore approaches for protecting fuel tanks on commercial aircraft. These approaches include filling fuel tanks with ESF, as is currently done on KC-130J aircraft, or inerting fuel tanks, as is currently done on V-22 aircraft. Both ARAC efforts included cost-benefit analyses, which evaluated cost-benefit during limited time frames: 10 years in the 1998 ARAC effort and 15 years in the 2001 ARAC effort. Within the NAVAIR acquisition community the economic ownership case of any system, subsystem, or aircraft change is assessed typically for the projected operational service life (OSL) of the aircraft, which can extend beyond 40 years.

The ownership cost analysis described in this presentation focuses on: 1) the projected TOC of keeping the ESF system now being supplied with KC-130J, 2) the projected TOC of implementing fuel tank inerting in lieu of ESF, including retrofit to aircraft already fielded with ESF, 3) and indicates how the impact of inerting system design requirements affect the ownership cost outcome. Non-recurring engineering, production, and recurring operations and maintenance costs are evaluated. Additional analysis also considers C-130J characteristics and procurements to develop an assessment that estimates ownership costs for the entire “J” community.

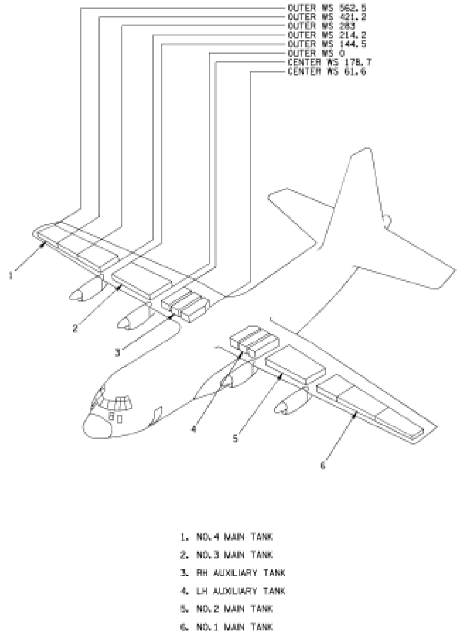
Background

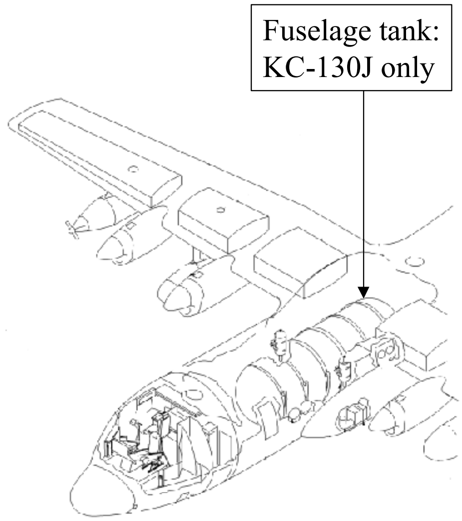
- Fuel Tank Ullage Protection
  - Passive (in-situ):
    - Explosion Suppressant Foam (ESF) on P-3, C-130, F/A-18
    - Aluminum mesh - not employed on Navy aircraft
  - Inerting:
    - Halon 1301 was used on now-retired A-6 platform
    - *Alternative*: On-Board Inert Gas Generation System (OBIGGS) - provides nitrogen-enriched air; maintain O2 concentration $\leq$ 9% for military applications
      - Implemented on V-22, H-1 Upgrades
  - Active Systems (within ullage, reacts to event):
    - Not employed on Navy aircraft
    - Technology status was subject of NGP study

Background (cont'd)

- USN KC-130J Aircraft Procurement
  - Piggy-backed to USAF C-130J "COTS" Procurement
  - C-130J fuel tank explosion protection requirement:
    - Electrically conductive reticulated foam shall be installed in all fuel tanks…….
      - Reticulated, polyether polyurethane, explosion suppressant charcoal colored, Type IV (coarse pore) conductive foam per MIL-F-87260(USAF)
      - Referred to as Explosion Suppressant Foam (ESF)
        - » Creates a locally rich area due to fuel wetting, which prevents passage of flame front and confines the pressure rise to small volume

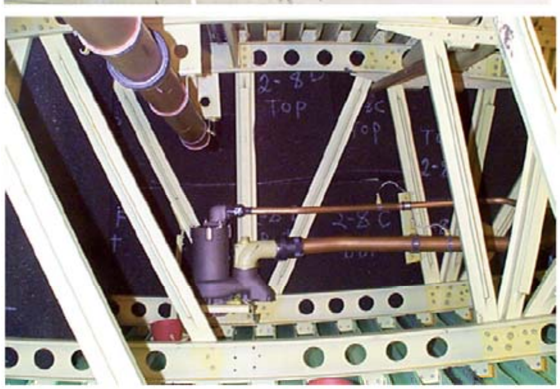
Fuel Tank Arrangement





ESF Installation

Wing tank with ESF installed



Wing tank internal view, looking inboard as ESF is being installed

Background (cont'd)

- KC-130J Program, NAVAIR PMA-207:
  - Investigation of weight reduction opportunities
    - ESF weight penalty (nominal density = 1.3 lbs/ft^3)
      - KC-130J = 1,666 lbs (main, auxiliary & external tanks)
      - C-130J = 1,192 lbs (main & auxiliary tanks)
  - Consider unprotected fuselage tank
    - Evaluate OBIGGS to inert all fuel tanks in lieu of ESF
      - Note: FY03 testing planned to characterize fuselage tank flammability
    - Leverage NAVAIR participation on ARAC FTIHWG
  - Constraints
    - Assume bleed air system cannot be used to drive air separation modules (ASMs)
    - Tanks remain inert during emergency descent

OBIGGS Assessment

- Previous C-130 analysis:
  - Report AFWAL-TR-82-2115, "Aircraft Fuel Tank Inerting System," July 1983
  - System weight: 190 lbs (most likely just the ASMs)
  - ASM technology: Hollow fiber membranes (4 ASMs)
  - ASM air supply input: provided by ECS
  - Ownership Cost:
    - $203.8M (vs $675M for ESF) - constant year (CY) dollars
    - Based on **674** aircraft, plus 10% spares
    - Rough estimate in 2001 CY dollars: $350M (vs $1.1B for ESF)

OBIGGS Assessment (cont'd)

- KC-130J Analysis:
  - Vendor-provided OBIGGS sizing analysis
    - Utilized ULLAGE math model (Seibold D.W., Report AFWAL-TR-87-2060)
  - Estimated total system weight: ≈475 - 500 lbs
  - ASM technology: Hollow fiber membranes
    - (< 4 ASMs, < 190 lbs)
  - ASM air supply input: Dedicated compressor (100+ lbs)
  - Ownership Cost:
    - Based on 79 aircraft, plus 10% spares
    - NAVAIR cost analysis - following slides

NAVAIR Cost Analysis

- Cost Modeling Assumptions
  - Utilized approach from AFWAL-TR-82-2115 with some modifications
    - Extended analysis over projected KC-130J operational service life (OSL) of 40 years
      - AFWAL-TR-82-2115 analysis is for 20 years
      - ARAC FTIHWG effort only looked at a 16-year period
    - Utilized KC-130J mission that included aerial refueling operations
    - Expanded OBIGGS maintenance cost analysis and also included spares replenishment
      - No spares replenishment identified in AFWAL-TR-82-2115
    - Interviewed ESF maintenance personnel; witnessed maintenance activities; incorporated actual hours

NAVAIR
Cost Analysis (cont'd)

- Cost Modeling Assumptions (cont'd)
  - Modifications to AFWAL-TR-82-2115 approach (cont'd)
    - OBBIGS maintenance hours scaled from V-22
    - Utilized MTBFs & MTBMAs from ARAC FTIHWG
    - NRE for ESF based on 1998 ARAC ESF cost for a single tank; NRE is scaled based on tank quantity
      - No ESF NRE identified in AFWAL-TR-82-2115
    - Utilized ARAC FTIHWG man-hour estimates to determine airframer OBIGGS NRE & production costs
  - Utilized escalation model developed by NAVAIR Cost Analysis Dept. & indices generated by Naval Center for Cost Analysis (NCAA)

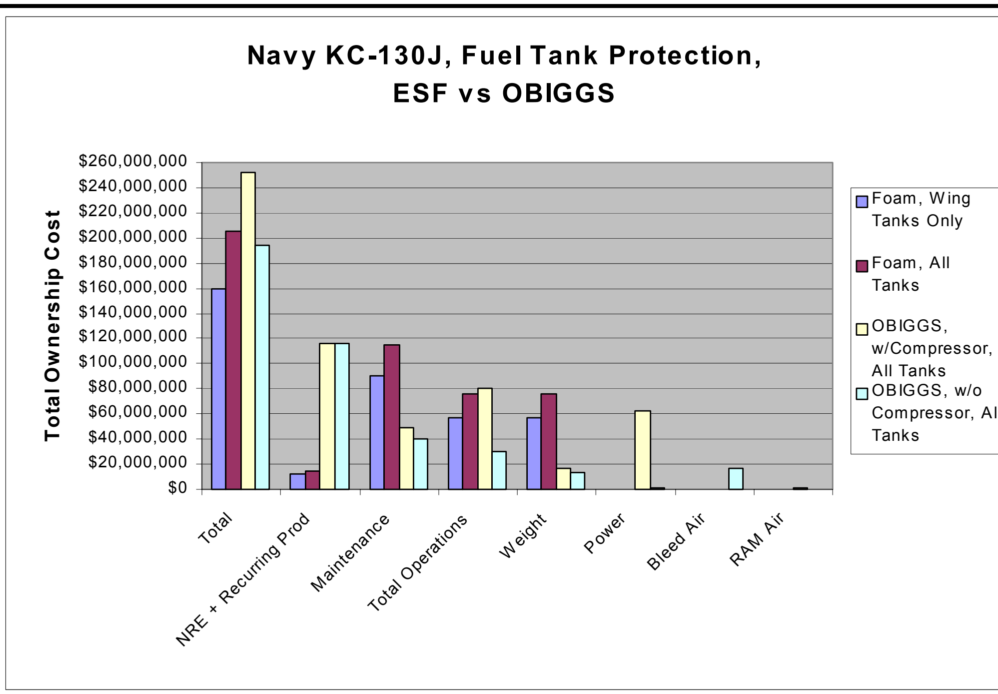
NAVAIR
Cost Analysis (cont'd)

- Cost Modeling Assumptions (cont'd)
  - ARAC FTIHWG parametric sizing not applicable: does not apply to OBIGGS sized for an emergency descent requirement
  - Assumed linear step change in mission-segment calculations for bleed/ram air penalties (changes relative to altitude are non-linear)
    - Conservative assumption
  - KC-130J (and C-130J) are already in production (and some already delivered) - ESF installed
    - ESF removal and OBIGGS retrofit would be required for aircraft built/delivered

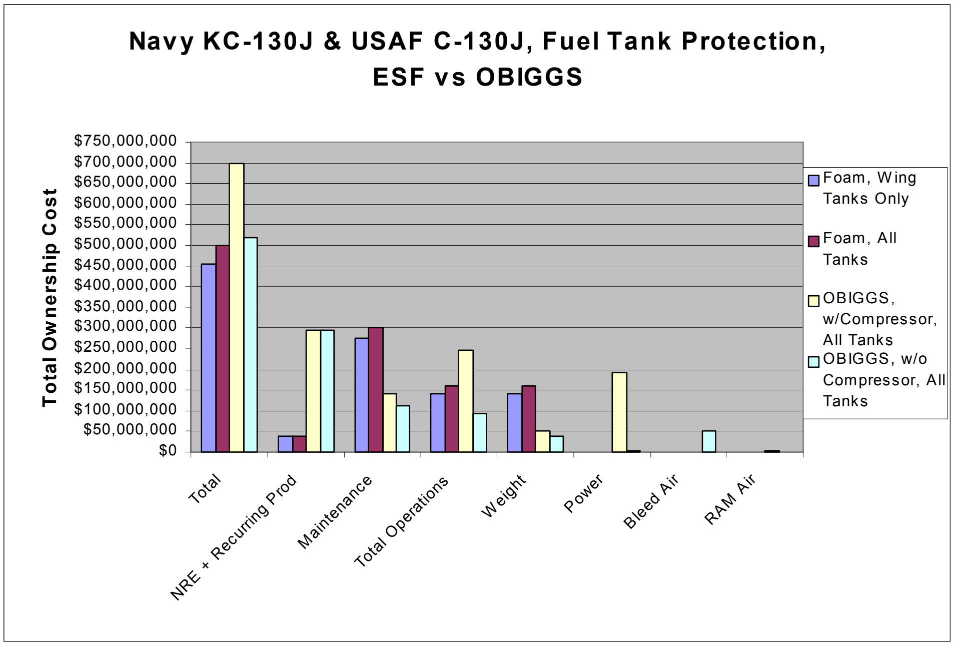
NAVAIR
Cost Analysis (cont'd)

- Cost Modeling Assumptions (cont'd)
  - OBIGGS case "w/o compressor" assumes same NRE & production costs as case "w/compressor"
    - Those costs not available
    - BUT, cost for airframer integration into bleed air system also not available

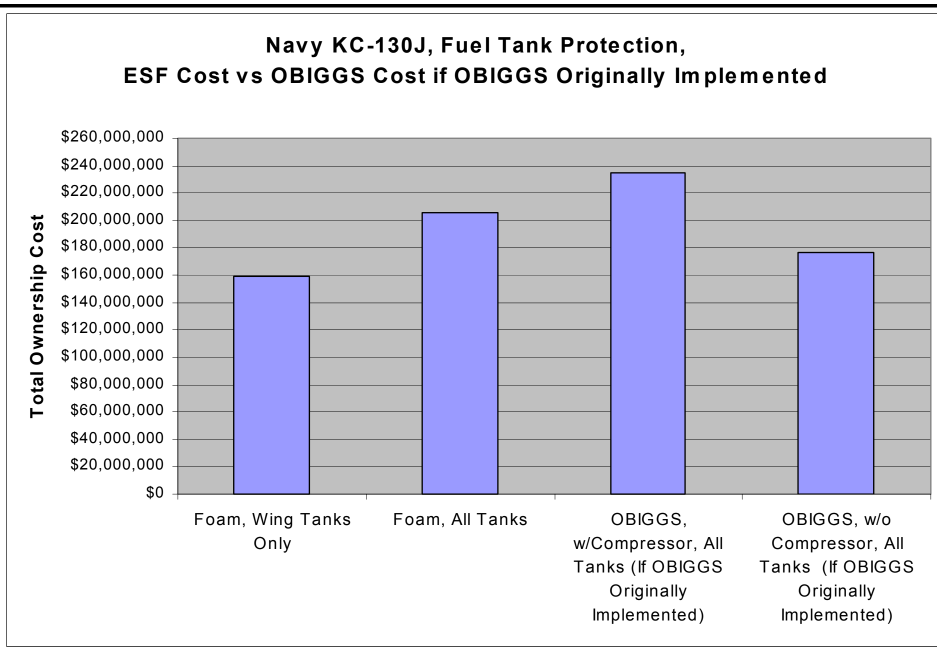
KC-130J Results
(CY Dollars)



"What-if" KC-130J & C-130J Aircraft Are Considered?
(CY Dollars)

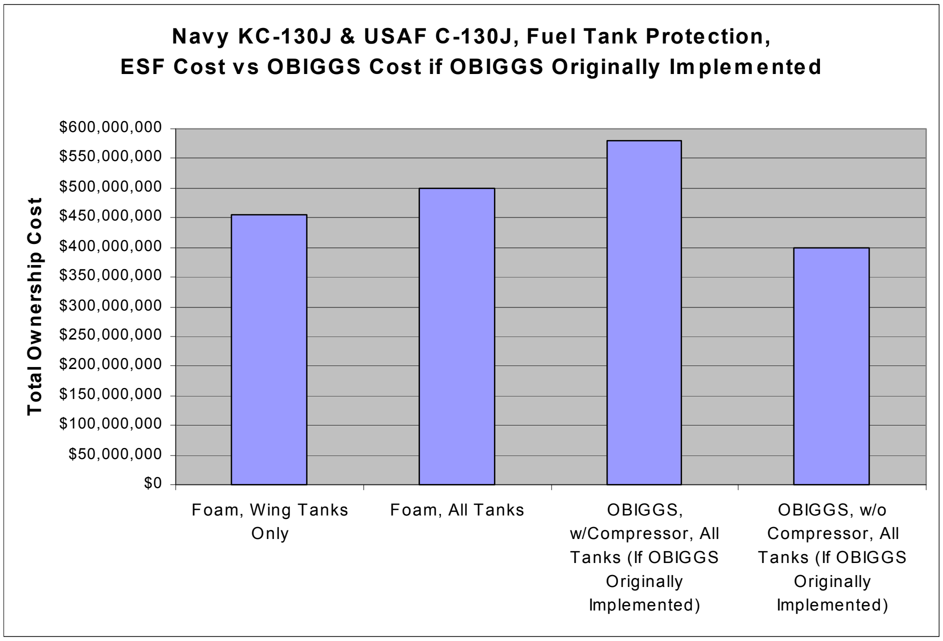


"What-if" OBIGGS Originally Implemented on KC-130J?
(Assumes Non-COTS Procurement, CY Dollars)



“What-if” OBIGGS Originally Implemented on KC-130J & C-130J?

(Assumes Non-COTS Procurement, CY Dollars)



Conclusions/ Recommendations

- KC-130J: Continue with ESF - lowest ownership cost given that aircraft are in production
  - No Navy-airframer data to support that OBIGGS case “w/o compressor” is feasible
    - When all KC-130J and C-130J aircraft are considered, this case is also slightly more costly than ESF in all tanks (including fuselage tank)
- *Assuming a Non-COTS procurement*, “What-if OBIGGS implemented originally on all -130Js” scenario (w/o compressor) is in general agreement with previous work
  - OBIGGS ownership cost < ESF ownership cost

Conclusions/ Recommendations

- New aircraft acquisition/development programs (vs COTS) considering fuel tank protection need to plan/design for adequate aircraft resources to implement OBIGGS cost effectively
- Recommended Future Work:
  - Optimize mission-segment penalty calculations
  - Refine maintenance man-hour modeling
  - Develop parametrics for OBIGGS similar to ARAC FTIHWG that provide emergency descent protection
    - Also need to model potential system unit cost differences due to varying aircraft delivery quantities
  - Promote modeling to support new acquisition programs

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