FTTS Concepts & Analysis Overview

Briefer:
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As of 2-Dec-02

Tank-automotive & Armaments COMmand
Agenda

- Pre-Milestone A Development Process
- QFD Process
- Concepts Overview
- Analysis Overview
- Concluding Remarks
FTTS QFD Process
Define and Prioritize FTTS Objectives, Attributes, and Potential Technology Solutions
FTTS QFD Members

NEEDS
Non-Accocate Exploratory Evaluation Decision Support

SPEARHEAD OF LOGISTICS

BOEING PHANTOM WORKS

PROJECT MANAGER

HTV
HEAVY TACTICAL VEHICLES

TEAM

BOEING

UNITED STATES ARMY
NAC
NATIONAL AUTOMOTIVE CENTER

Advanced Concepts

Committed to Excellence
FTTS Operational Objectives

• Quickly deploy anywhere in the world
  – Be transportable by inter/intra-theater land, sea and airlift [anywhere in the world]
  – Be self deployable and re-deployable
  – Be inserted with combat units into austere theater through multiple unimproved entry points [without relying on fixed ports and staging bases]

• Perform its operational role
  – Operate immediately upon arrival (RO/RO)
  – Transport the personnel, cargo, and equipment to the “right place” at the “right time” to support the geographic combatant commander
  – On-load/off-load the personnel, cargo, and equipment
  – Increased operational time

• Keep pace with the combined arms unit (on the ground) in the Unit of Action
  – On the ground maneuver with the Combined Arms Unit over operational distances
  – Be self-sustainable for up to 7 days in low-end conflict and peace time military engagement
  – Support adaptive training enabling team proficiency

• Reduce logistics footprint
Operational Objective Priorities – “Parents”

- Perform its operational role
- Reduce logistics footprint
- Quickly deploy anywhere in the world
- Keep pace with the combined arms unit (on the ground) in the Unit of Action
Operational Objective Priorities – “Children”

“Reduce Logistics Footprint” is significantly longer because of its roll as both a “parent” and a “child.” See Operational Objective Priorities A (chart 11)
FTTS Attributes

- Be C-130 transportable (weight and size)
- C-17 Dual Row Compatible
- Be rail transportable
- Be sea-vessel transportable
- Be CRAFT transportable
- Be rotorcraft transportable (sling-loaded)
- Be advanced vertical lift transportable
- Be SSTOL Transportable
- Be airdrop capable
- Fit inside an ISO container
- ISO-compatible
- Flatrack compatible
- Module compatible
- Shelter compatible
- Situational Awareness
- Be network centric (capable of receiving real time situational info...)
- Able to self-protect (incl. detect/avoid mines)
- Mitigate enemy/conflicts affects (NBC/Ballistic protection) (given a hit)

- Meets US and NATO highway reqm’ts.
- Have common set of operational interfaces (Crew station/ C4I Suite)
- MANPRINT
- Vehicle transmodal compatibility (air/sea/land)
- Vehicle transloading interface
- Enable significant consumables sustainment effectiveness and efficiency (water, power, POL)
- Backward compatible
- All climates capable
- Provide unsurpassed mobility (terrain and water)
- Reduce reliance on non-combat materiel requirements
- Be re-configurable (across proponents)
- Improved reliability
- Improved maintainability
- Mission Planning
- Able to refuel / recharge in-transit
- Able to be fully combat loaded in-transit
Matrix A: Operational Objectives & Attributes

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<thead>
<tr>
<th>(Hows) FTTS Attributes</th>
<th>Be C-130 transportable (weight and size)</th>
<th>C-17 Dual Row Compatible</th>
<th>Be rail transportable</th>
<th>Be sea-vessel transportable</th>
<th>Be C2RAF transportable</th>
<th>Be rotorcraft transportable (sling-loaded and internal)</th>
<th>Be Ultra Large Airship Transportable</th>
<th>Be SSTQ Transportable</th>
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<th>ISO-compatible</th>
<th>Flatrack compatible</th>
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<td>Be inserted with combat units into austere theater through multiple unimproved entry points [without relying on fixed ports and staging bases]</td>
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9 = Strong
3 = Moderate
1 = Weak
0 = None/Negative Impact
FTTS Technologies

- Propulsion Technologies (Engine/Transmission Combinations)
  - Advanced Low Emission High Density Diesel Engines/conventional transmission
  - Hybrid Technologies / hybrid electric powertrain
  - Turbine Engine Hybrid
  - Beltless Engines
- Suspension / Steering System
  - Active Suspension
  - Semi-Active Suspension
  - Improved conventional independent suspension
  - Variable height hydro-pneumatic independent suspension
  - Electronic Steering (in hub motors)
  - Ackerman Steering
  - Hybrid Ackerman Steering

- C4I
  - Drivers vision aids
  - Synthetic Vision / Pilot Aids / 3-D Imagery
  - Helmet Mounted Display & Tracking Sys.
  - Night vision aids (thermal, IR, Microbolometer Vision Camera ...)
  - Peripheral vision aids
  - Image Fusion on Re-configurable/ Multifunction Displays
  - Speech recognition
  - Embedded diagnostics and prognostics
  - Real-time Information in the "Cockpit" (RTIC)
  - En Route Mission Planning and Rehearsal System
  - Robotics
  - Voice Communications Collision Avoidance
  - Movement tracking system
  - RF AIT (Radio Frequency Auto Id Technologies)
FTTS QFD Technologies

- Mission Modules / Materiel Handling
  - Smart Distribution System
  - Intelligent Load Handling System
  - Modular Packaging
  - Smart Tie Down
  - Configured load-building software
  - Flatrack
  - CAIK
  - FAIK
  - MAIK
  - EDS-A
  - RPAD
  - Objective Flatrack/Modular Platform System
  - Vehicle Alignment System

- Truck Specific Technologies
  - Environmental control unit
  - Long life, low weight materials
  - Onboard oil analysis
  - Single lubricant system

- Lube for life components
- Onboard water generation
- Onboard power generation
- Onboard weighing/shock sensor

- Survivability
  - Base cab armor
  - Modular/appliqué armor
  - Active Protection System, limited
  - Defensive Aids Suites (DAS)
  - Self-Defense Weapon
  - NBC Overpressure
  - Signature Management

- Aircraft/Vehicle Interfaces
  - Autonomous Cargo Handling/Load by Wire
  - C4I Interface
  - In-Flight Vehicle Refuel Technology
  - External Aircraft-to-Vehicle Refuel Technology
  - In-Flight Battery Charging Technology
  - In-flight load attenuation
Technology Linkage to Attributes

- 58 Technologies in the areas of Propulsion, Suspension/Steering System, C4I, Mission Modules/Materiel Handling, Truck-Specific, Survivability, and Aircraft-Vehicle Interface were examined

  - Most of the 16 C4I technologies score in the top half; Image Fusion on Re-configurable/Multifunction Displays, Embedded Diagnostics & Prognostics, C4I Interface, Night Vision Aids, and Real-Time Information in the Cockpit score significantly above other C4I items
  - Active & Semi-Active Suspension score significantly better than Improved Conventional Suspension
  - Hybrid Technologies / Hybrid Electric Powertrain scores significantly better than other propulsion alternatives
  - Smart Distribution technologies
  - All 8 of the truck-specific technologies score in the top half
  - Objective Flatrack scores significantly better than CAIK, FAIK, …; without CAIK, FAIK, … compatibility, however, the attribute of backward compatibility becomes an issue
Technology Linkage to Attributes

- Autonomous Cargo Handling / Load by Wire rises above other aircraft-vehicle interface items; other items (x) are unique contributors to desirable attributes.
- The lack of survivability technologies is a reflection of the process rewarding breadth over depth; Defensive Aids Suite scores above other survivability items, yet without the other survivability technologies then the attributes of Able to self-protect (avoid the threat) and Mitigate Enemy Affects (Given a Hit) become issues.
- Electric Steering scores significantly better than the Ackerman and Hybrid Ackerman alternatives.
- In-flight Vehicle Refuel Technology and In-Flight Battery Charging Technology were the only technologies that satisfied the need to refuel/recharge in transit.
- Being C-17 Dual Row Compatible and Rail Transportable are fall outs of strict weight and height requirements of the C-130.
- Being Sea Vessel Transportable lowers the weight and height requirements of the C-130, but requires that the truck be able to maneuver in order to drive onto the ship.
FTTS Concepts
FTTS Maneuver Sustainment Vehicle Concepts

- 5 FTTS 11 Ton Payload Configurations Completed
  - GVW, range, fuel consumption, protection level, payload center of gravity, calculated
- Powered Trailer 11 Ton Payload Configuration Concept Completed
- Concepts submitted to Ft. Knox (MMBL) for inclusion in FCC2 CEP, June 01
- Concept animated June 01 and shown at Transportation School Regiment Week
- 3 FTTS 12/16 Ton Payload Configurations Refined
- Manned & Robotic 2.5 Ton Payload Concepts completed
- Manned 7 Ton Payload Concept completed
- Powered Trailer 7 Ton Payload complete
  - GVW analysis complete
- Robotic 7 Ton Payload initiated

FTTS Utility Vehicle

- 1 FTTS UV Concept Complete
FTTS MSV 7 Ton Characteristics

**Cab Seating:** 3 Man  
**Axle Configuration:** 6 X 6  
**Curb Weight:** 23,827 lbs (10,808 kg)  
**Gross Vehicle Weight Rating (GVWR):** 37,827 lbs (17,158 kg)  
**Length:** 372” (9,450 mm)  
**Width:** 96” (2,438 mm)  
**Height (cab):** 102” (2,590 mm)  
**Wheel Base:** 249” (6,325 mm)  

**Maximum Speed:** 65 mph (105 kph)  
**Tires:** 395/85R20  
**Number of Tires:** 6  
**Central Tire Inflation:** Yes  
**Fuel Capacity:** 120 gal (455 liter)  
**Cruising Range:** TBD  
**Air transportability:** C130, C141, C-17,C-5, CH-47 & CH-53  
**Engine:** Cummins 400 hp Diesel  
**Transmission:** Series Electric Drive  
**Suspension:** Independent, trailing Arm
FTTS (11 Ton Payload)
Technology Range Overview

Concept 1: Emerging Technologies
- Electronic Steering
- Hybrid Electric Drive
- Variable Height Suspension
- Advanced Diesel Engine
- Combat Hybrid Power System

Concept 2: Improved Conventional Technologies
- Ackerman Steering
- Advanced Transmission
- Independent Suspension
- Diesel Engine

Concept 3: Hybrid
- Ackerman & Electronic Steering
- Electric Drive
- Variable Height Suspension
- Diesel Engine
- Combat Hybrid Power System (CHPS) Architecture

Concept 4: Robotic Technologies
- Semi-Autonomous
- Hybrid Electric Drive
- Variable Height Suspension
- Advanced Diesel Engine
- Combat Hybrid Power System

Concept 5: Sideloader
- Concept 2 with Side Loader

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FTTS MSV Refined Concepts

MSV 2 Concept

Advanced Conventional
- Cab: 2 Man
- Axle Configuration: 8x8
- Weight: 32,550 lbs (14,795 kg)
- GVW: 59,540 lbs (27,063 kg)
- Tires: 16R20
- Engine: Cummins 600 hp Diesel
- Transmission: Allison Automatic
- Suspension: Arvin Meritor Independent

MSV 3 Concept

Hybrid Electric
- Cab: 2 Man
- Axle Configuration: 8x8
- Weight: 26,315 lbs (11,960 kg)
- GVW: 53,305 lbs (24,230 kg)
- Tires: 16R20
- Engine: MTU 199
- Transmission: Series Electric
- Suspension: Independent Trailing Arm

MSV 4 Concept

Robotic
- Cab: 1 Man Backup
- Axle Configuration: 6x6
- Weight: 18,554 lbs (8,430 kg)
- GVW: 44,804 lbs (20,365 kg)
- Tires: 16R20
- Engine: MTU 199
- Transmission: Series electric
- Suspension: Independent Trailing Arm

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FTTS MSV Unit of Action Modules

TUAV Carrier

Cargo

Water Tanker

Fuel Tanker

Fuel Station

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FTTS Survivability Technology

- **Mine Blast Protection**
  - Shaping - V
  - Spall Liner
  - Applique

- **Armor**
  - Modular
  - Hvy MG
  - Frag

- **Transparent Armor**

- **Variable Height Suspension**
  - Hull for reduced Signature

- **XM 307 (OCSW)**

- **Defensive Aids Suite**

- **NBC**
  - Carbon filter
  - Overpressure

- **All electric mode**
  - Limited silent operation
  - No smoke plume

- **8 independently controlled in hub electric motors for graceful degradation**

- **Redundant Power**
  - Diesel
  - Limited battery
FTTS MSV 3 Mobility Technologies

- Advanced Diesel Engine
- Integrated Crewstation
- Energy Storage
- Frame, Carbon Steel
- Motor Inverters
- H2O from Exhaust
- 16Rx20 Tires w/ run flat & CTIS
- In-Hub electric drive motors
- Variable Height Independent Suspension

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FTTS-U-SPT
FTTS-U-AMB
FTTS-U-C2
FTTS-U (Troop Carrier)
FTTS-U-SPT (Troop Carrier)

Cab Seating: 2 Man
Axle Configuration: 4 x 4
Curb Weight: 9,072 lbs (4,124 kg)
Gross Vehicle Weight (GVW): 14,772 lbs (6,715 kg)
Length: 221” (5,613 mm)
Width: 86” (2,184 mm)
Height: 90” (2,286 mm)
Track: 74” (1,880 mm)

Maximum Speed: 65 mph (105 Kph)
Tires: 37X12.50 R17 LT Wrangler MT/R
Central Tire Inflation: Yes
Fuel Capacity: 45 gal (170 liters)
Air Transportability: C130, C141, C17
Engine: 3056 CAT
Transmission: Electric Drive
Suspension: Independent w/Variable Damping
FTTS-U Technologies

XM307, (OCSW)
3056 CAT Diesel Engine
CTIS
Energy Storage 2-Dec-02
In-Hub electric motors
Independent Suspension w/Variable Damping
Integrated Advanced Crew Station
37 R17 Tires w/ run flat

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Integrated Crew Stations

Secondary Armament/Self-Defense Water Generation

NBC Filtration & Overpressure Energy Storage

C4I Components Variable height, semi-active suspension

Central Tire Inflation System

Electronic Architecture

Electric drive components

FTTS & FCS HTI Potential
FTTS Analyses
FTTS Analyses Overview

Mobility
- Dynamic Analysis & Design System (DADs) - (TARDEC)
  ✔ NATO Reference Mobility Model (NRMM) - (TARDEC)

Operational
- ✔ VCAM (Vought Combined Arms Model) - (Lockheed Martin)
  Future Combat Command & Control (FCC2) CEP - (MMBL)

Cost
- Unit Production Cost Estimates - (TACOM)

Other
- ✔ Crew Station Human Factors/ Task Analysis - (ARL-HRED)
  Cargo Handling Equipment - (ARDEC Log R&D)
Mobility Analyses Performance Metrics

- **Vehicle Dynamics (DADS)**
  - Max longitudinal and lateral slope
  - Max obstacle avoidance lane change speed
  - Max vertical step height (depth)
  - Ride quality at Driver’s Station
    - Six Watt speeds vs. terrain RMS
    - Three g. peak load speeds vs. half round bump radii

- **Vehicle Mobility (NRMM)**
  - Percentage of terrain maneuverable and causes of NOGO conditions
    - ground clearance, tractive effort, trailer impacts
Mobility Analyses Approach

- Use M&S (DADS) to compare FTTS Concepts 1, 2 & 3 with baseline HEMTT 977

- Quantify mobility technology performance
  - Skid steer vs. Ackerman steer
  - Hub motor drive vs. standard power train drive
  - Active suspension vs. passive suspension
  - Combinations of these
  - Coupled trailer vs. autonomous detached follower
Scenarios

- **Germany**
  - Dry
  - Wet
  - Wet/Slip
  - Snow

- **Middle East**
  - Dry
  - Sand
Primary Roads
  • Paved Roads

Secondary Roads
  • Dirt and Gravel Roads

Trails
  • Around trees
  • Around large obstacles
  • RMS up to 3.0

Cross-country
  • Through trees
  • Over large obstacles
  • RMS up to 5.0
    • 3.0-5.0 (0.2% in Germany)
    • 3.0-5.0 (6.8% in Middle East)
FTTS MSV NRMM Conclusions

Ride quality results (6 Watt Speeds) over 3” RMS

• ALL Active FTTS Variants modeled were able to obtain 6 Watt speeds
• in excess of 30 - 32mph (at the drivers station).
• FTTS Independent Suspension w/o active control: 24mph.
• The HEMTT reached 6 Watts at 16 mph over the same profile

Independent Suspension
• slight increase in Mission Rating Speeds (MRS)
• higher % no-goes

Active Suspension
• significant increase in MRS
• lower % no-goes

Ackerman Steering of FTTS MSV 2 better than FTTS MSV 3
FTTS mobility performance (cross country speeds, slope negotiation, vertical obstacle, ..) can be weighed against cost and FCS mobility parameters and op tempo support requirements

Impact the FTTS MNS/ORD/PD

e.g.
(FTTS shall negotiate a 32” vertical obstacle,...)
(Driver will absorb no more than 6 watts of energy traversing rough cross country terrain at 25 mph..)
Collaboration with the Army Research Laboratory
Crew Station Human Factors/ Task Analysis - (ARL-HRED)

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<tr>
<th>Baseline</th>
<th>FY 02-03 - Model</th>
<th>FY 03 Validate HFTT - Soldier Interface</th>
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| Interviewed current heavy tactical truck operators and maintainers to identify:  
  - Features to preserve, change, or add in future designs  
  - Capabilities needed to support FCS missions  
  - Design requirements for the modular truck concept | Assisting TARDEC in crew station design with human figure modeling and workload modeling support.  
  - Workload modeling based on the task analysis developed by HRED and on information gathered during the user interviews. | Design, conduct, and interpret studies to validate the workload modeling, possibly using TARDEC simulators or other surrogates for notional future truck systems. |

IMPRINT Workload Models

Human Figure Models

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FTTS Operational Modeling

- **Lockheed Martin’s FCS Force Platforms, Technologies, Operations and Re-supply structure**
- **Blue Tactical Platforms**
  - HEMTT LHS Baseline (11T payload)
  - TARDEC FTTS MS Concepts 1, 2 & 3 (10T payload)
  - No trailers
- **Vignette**
  - SW Asia
  - Secure airfield and resupply an FCS Battalion in the Forward Area over a 4-7 day period
  - Medium capable RED force
- **Metrics (MOE’s)**
  - Quantity of supplies delivered to forward area
  - Time to deliver
  - FTTS and HEMTT vehicle losses
Assess Mobility Technology benefits
- Increased fuel economy (hybrid electric drive)
- Increased cross country speed (independent suspension, ground clearance, power to wgt ratio, etc)

Assess Survivability benefits
- Fewer vehicle losses/more supplies delivered
  - Armor (HMG & Artillery Fragment protection)
  - Signature management (RF/thermal)
  - Fixed & Limited APS (RPG only)

Assess C4I benefits
- % time LOS communication possible (supply tempo)
FTTS Operational Modeling Results (Phase I)

- **Mobility**
  - Increased fuel economy of concepts 1 & 3 translates into a 25% increase in Class (fuel) supplied to FASC
  - Increased cross country speed had no effect due to route selection
  - Idle fuel consumption is a major contributor impact of total fuel consumption

- **Survivability**
  - FTTS Armor results in a 10% survivability increase (14 FTTS v. 15 HEMTT losses)
  - Limited APS results in a 36% survivability increase survivability (10 FTTS v. 15 HEMTT losses)
  - Self Defense weapon (OCSW) needs target acquisition tailored for hand held ambush threat to be effective

- **C4I**
  - Line of Sight Communication available 55% of the time
Representative VCAM Output
Day 3 Sufficiency

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HEMTT 977

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<td>100.00%</td>
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FTTS 1

2-Dec-02
VCAM Phase I Operational Modeling Conclusions

Technology Specific

- FTTS delivers more supplies than the baseline in the scenario modeled due primarily to survivability technologies (armor & limited APS)
- FTTS mobility improvement was not significant to supply performance due to terrain and routes selection
- VCAM did not directly link C4I technology contributions to supply performance

Operational Insights

- Tactical Mistakes
  - Insufficient Escort On 1st Sortie Attempt
  - Did Not Provide A Sanitized Route (Sortie 2)
    - Free of Mines
    - Cleared of Booby Traps
- Routing Near Any Population Center Should Be Avoided At All Costs
- FASC Should Be Moved Preemptively As Time/Terrain Permit
- Rear Area Security Remains a Key Issue
  - Static Preemptive UAV Orbits Over Built Up Areas Could Be Required
FTTS STO Path Forward

- **FTTS MSV**
  - Execute Operational Modeling
    - VCAM Phase II
  - Incorporate initial mobility results into designs
    - Suspension/Steering refinement
    - Rerun DAD’s & NRMM with updated designs
  - Link survivability technologies to FCS O&O

- **FTTS UV**
  - Complete technology assessments
  - Complete range of designs
  - Conduct requested analyses

- **Current Fleet**
  - Continue to support NAC & PEO in technology application