U.S. Army Research, Development and Engineering Command

Analytical Approach using MUVES-S2/ORCA Modeling in Support of the Joint Cargo Aircraft (JCA)

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TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Richard Moyers and Penny Willard

U.S. Army Research Laboratory
Survivability/Lethality Analysis Directorate

Outline

- Background
- ComputerMan/Pilot Survey (CMPS) Methodology
- Operational Requirement-based Casualty Assessment (ORCA) Methodology
- Job Description Development
- Joint Cargo Aircraft (JCA) Jobs
- Mission Scenarios
- ORCA Personnel Inputs
- JCA Vulnerability Analysis
- Conclusion

Background

- Ballistic vulnerability analysis was a joint effort between the U.S Army Research Laboratory, Survivability/Lethality Analysis Directorate (ARL/SLAD) and the U.S. Air Force Aeronautical Systems Center Engineering Directorate (ASC/ENDA)

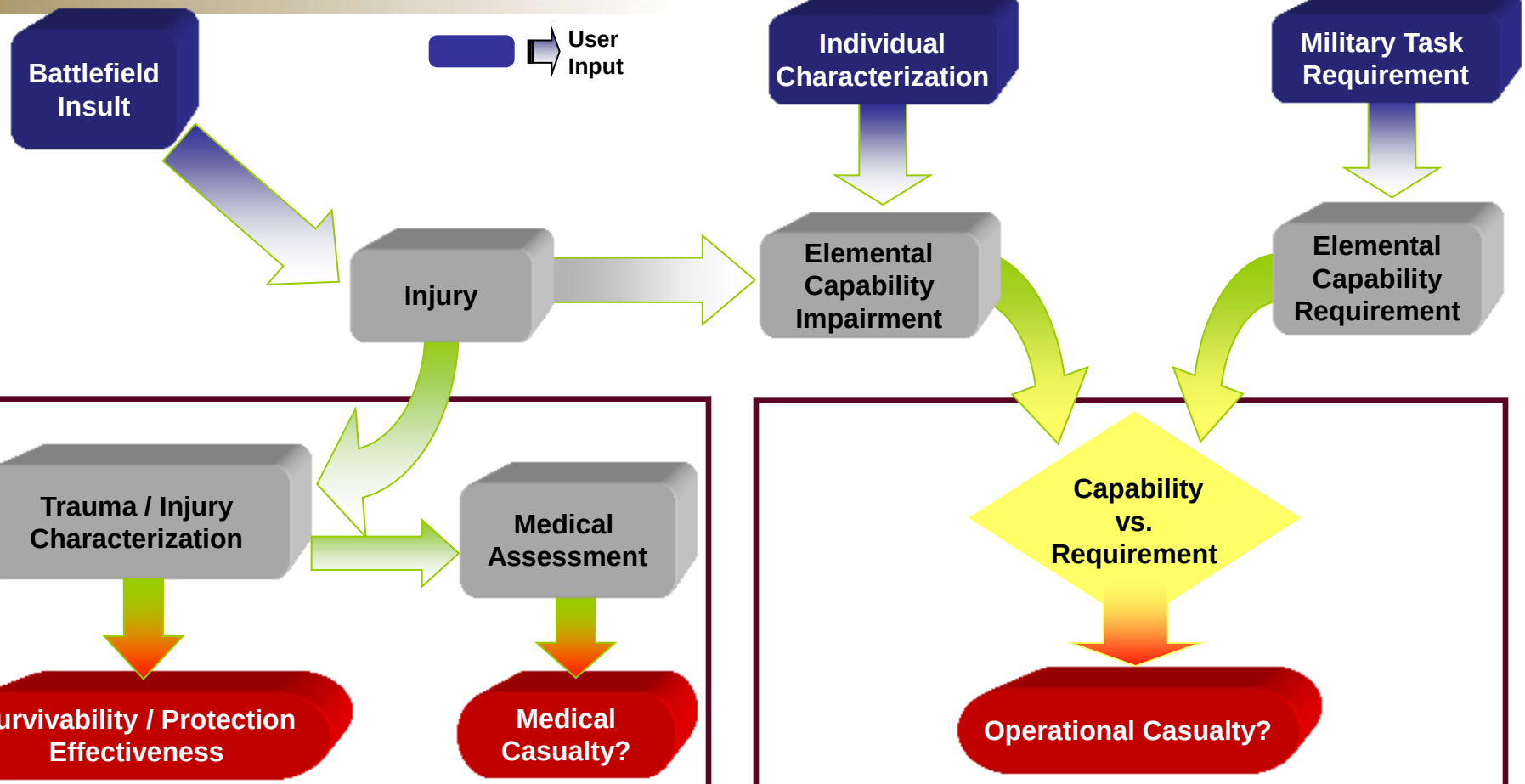
- Two analyses were conducted:
  - Crew vulnerability analysis
  - System-level vulnerability analysis

- Personnel configurations:
  - 4 Crew Members: pilot, copilot, two loadmasters
  - 44 Crew Members: pilot, copilot, two loadmasters, 40 troops in cargo area

CMPS Methodology

- ComputerMan/Pilot Survey (CMPS)
  - Evaluation methodology combined Computer Man's limb state performance with Pilot Survey results to predict residual functionality for an injured crew member
    - ComputerMan
      - Based on limb dysfunction
      - Assessed wound tract size and tissue retardation
      - Evaluated for 4 representative combinations: Defense - 30 seconds, Assault - 30 seconds, Assault - 5 minutes, and Supply -12 hours
      - Divided model into 81 Functional Groups (FGs)
      - Assessed against 3 levels of dysfunction: none, partial and total
    - Pilot Survey
      - Used to predict the crew's ability to continue to operate the aircraft after sustaining various levels of ballistic injury.
  - For aviation analyses, "Assault - 30 seconds" data was used to assess pilot and co-pilot residual functionality

ORCA Methodology



Survivability Metric (Injury)

- Typically Red on Blue analyses
- Focus is the survivability of Blue forces
- ORCA output metric: MAIS
- Example analysis: Vehicle up-armor programs

Lethality Metric (Incapacitation)

- Typically Blue on Red analyses
- Focus is the lethality of a Blue system
- ORCA output metric: Operational Casualty
- Example analysis: Munition lethality evaluation

Job Description Development

Job Description Process

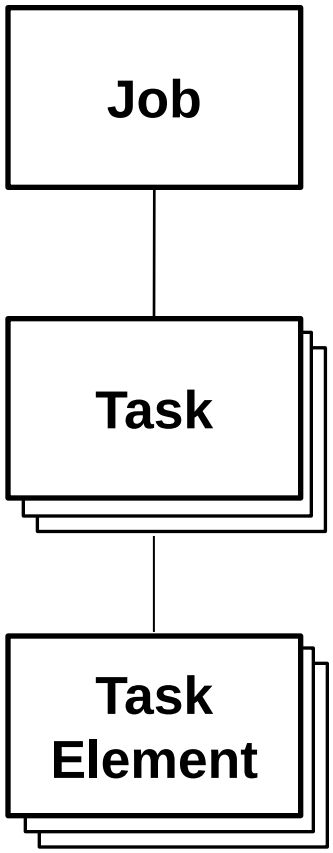
1. Identify the functional tasks that are likely to be called upon during the *context-sensitive* scenario.
    1. Define the scenario
    2. Confine the task list to the scenario!
2. Cull doctrinal / training manuals to decompose the tasks into their unique and discrete task elements (example: to get into the car, you must first open the door, followed by turning to seated position, and then close the door).
3. Consult SMEs and practical experience to quantify each task element into minimum (threshold) and full (objective) levels of performance within the Elemental Capability Vector (ECV).
4. Pursue verification and endorsement from SMEs.

Elemental Capability Vector *

Visual Acuity & Color Discrimination	Speech Articulation
Night Vision	Vocal Power
Visual Field of View	Right Leg Strength
Visual Binocularism & Motility	Left Leg Strength
Hearing Threshold – Low Freq.	Left Arm/Hand Strength
Hearing Threshold – High Freq.	Right Arm/Hand Strength
Binauralism	Left Arm/Hand Dexterity
Endurance	Right Arm/Hand Dexterity
Psychomotor Mental Processing	Torso Support
Cognitive Mental Processing	Head / Neck Movement
Visual Mental Processing	Somatic Senses
Auditory Mental Processing	Balance

*not in order

Job Decomposition



A *job* is defined as a list of an individual's *tasks*.

A *task* is made of *task elements*. A job can have one or more tasks.

A *task element* is a single activity with specific parameters. An instance of a task element is defined in the terms of elemental capabilities.

Example Job
Assaulting Infantry Rifleman

Engage Targets with an M4 or M4A1 Carbine

Load an M4 or M4A1 Carbine

Mount a NVS AN/PVS-4 on a M4/M4A1 Carbine

Zero a NVS AN/PVS-4 to a M4/M4A1 Carbine

Engage Tgts w/ M4/A1 Carbine Using NVS AN/PVS-4

Mount an AN/PAS-13 TWS on M4/M4A1 Carbine

Zero an AN/PAS-13 TWS to an M4 or M4A1 Carbine

Engage Targets with an M4/M4A1 Carbine Using a TW

Engage Targets w/ M4/M4A1 Carbine Using an AN/PAS-13

Operate a Night Vision Sight AN/PVS-8

Operate a Thermal Viewer, AN/PAS-7

Perform Safety Checks on Hand Grenades

Employ Hand Grenades

Engage an Enemy with a Bayonet

Move as a Member of a Fire Team

Engage Tgts w/ M4/A1/Carbine Using NVS AN/PVS-4

- With sight in operation assume appropriate firing position based on situation
- Identify targets in designated sector of fire
- Determine range to targets using the AN/PVS-4 reticule
- Fire on target until destroyed or told to cease fire

Employ Hand Grenades

- Position body remaining covered
- Grip grenade with lever down and pull ring free
- Arm grenade by removing safety clip and ring
- Confirm body alignment and keep eyes on tgt
- Throw grenade overhand with eyes on target
- Return to cover and concealment

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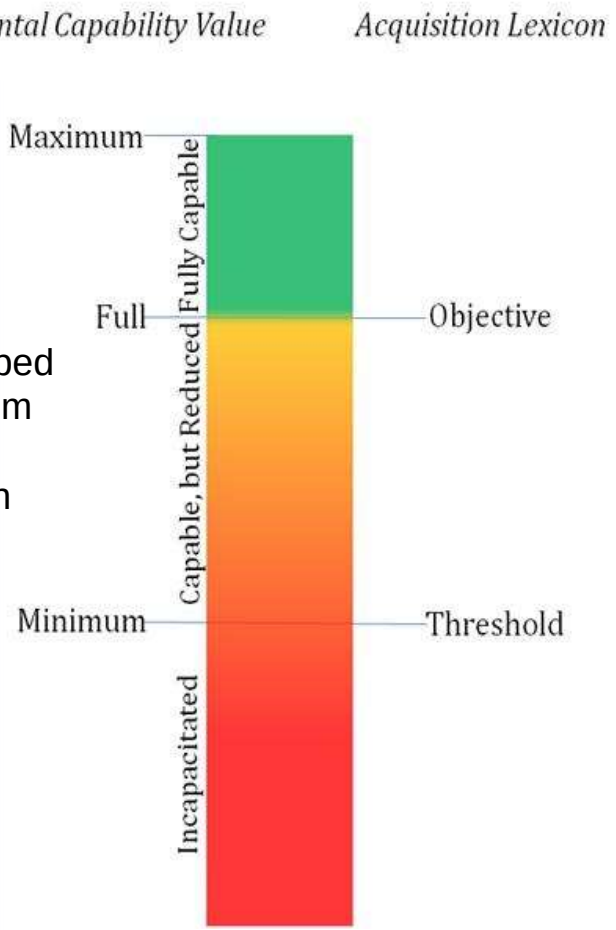
Each EC is described in both the minimum and full level of performance within the ECV.



What Jobs are Required for JCA ?

Pilot / Co-Pilot: The two people charged to jointly fly the aircraft.
*** Assume *redundancy* of functions.**

- **Airborne through Landing**
- **Descent through Landing**

GIBs: Personnel in the aircraft cabin: loadmasters and troops (aka "Guys in Back")

- **GIB Egress**

What Assumptions Did We Make About the JCA Jobs?

Due to the assumption of redundancy, these jobs were built by reversing the direction of the traditional ORCA job architecture.

Traditionally, a *Job* is mapped to a person.

***Vehicle Driver* = Crewman #1**

In the JCA, because the pilot and co-pilot have redundant capabilities dedicated to the singular purpose of flying the aircraft, the person was mapped to the *Job* functionally.

Crewmen #1 and #2 =
Pilot/Co-Pilot Airborne through Landing

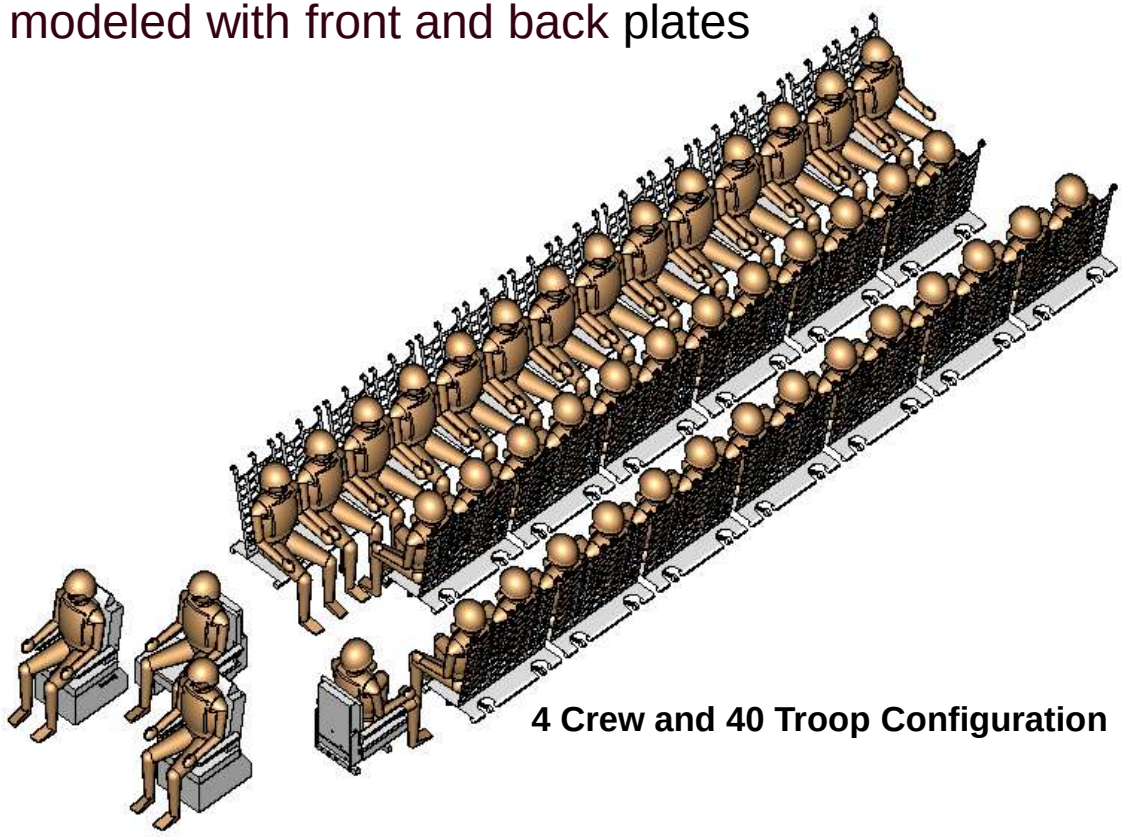
Mission Scenarios

		Mission Profiles		
		Long range cargo	Short range troop	Low altitude air drop
Vignettes	Takeoff	Threats: Armor-Piercing Incendiary (API) and Man-Portable Air Defense Systems (MANPAD) ORCA Job: Airborne → Landing	Threats: API's and MANPAD's ORCA Job: Airborne → Landing	N/A
	Cruise	Threats: High-Explosive Incendiary (HEI) ORCA Job: Airborne →Landing	Threats: HEI's ORCA Job: Airborne →Landing	Threats: API's and MANPAD's ORCA Job: Airborne →Landing
	Landing	Threats: API's and MANPAD's ORCA Job: Descent →Landing	Threats: API's and MANPADs ORCA Job: Egress & Descent →Landing	N/A

Personnel Inputs - Target Description

- The ORCA personnel geometry is inserted into the component-level target geometry and the ORCA man is articulated into the proper crew configuration.
- Body armor is modeled in the target geometry.
  - Pilot and Copilot modeled with front plates only and Air Warrior helmets
  - Loadmasters and troops modeled with front and back plates

ORCA man with front plate and helmet



4 Crew and 40 Troop Configuration

Personnel Inputs – Injury AIS/MAIS

- ORCA utilizes the Abbreviated Injury Scale© (AAAM, Version 2005 Update 2008)(AIS). AIS is an anatomically-based, consensus-derived, international severity scoring system that classifies each injury by body region according to its relative importance on a 6-point ordinal scale. AIS values provide information on the type, location, and severity of anatomical injuries. AIS scores each single injury.
- MAIS – Maximum Abbreviated Injury Score (MAIS) is an anatomical measure of injury severity. This score classifies injury severity on the basis of the single injury having the greatest AIS severity value. The MAIS is between 0 and 6.
- For the JCA analysis, if any crew member or troop received a serious or greater injury (MAIS ≥ 3) then the result is a mission abort.
- A serious Injury – An injury that requires immediate medical attention. Serious injuries present a serious threat to life.

MAIS	Injury Level	Type of Injury
1	Minor	Superficial
2	Moderate	Reversible injuries; medical attention required
3	Serious	Reversible injuries; hospitalization required
4	Severe	Life threatening; not fully recoverable without care
5	Critical	Non-reversible injuries; not fully recoverable even with care
6	Maximal	Nearly Unsurvivable

Personnel Inputs – Incapacitation Operational Casualty

ORCA provides operational metrics to determine if personnel have the capability to meet the requirements of the job under evaluation. There are six post-wounding times: immediate, 30 seconds, 5 minutes, 1 hour, 24 hours, and 72 hours.

- Operational 'Casualty'
  - Applied to each crew member for specific discrete times
  - If the task elements of all the tasks are greater than the minimum required performance level, then casualty equals 0 (able to perform job).
  - If one of the task elements is less than the minimum performance requirement, then casualty equals 1 (unable to perform job).

- For the JCA analysis, 3 failure modes were evaluated:
  - Loss of Pilot
  - Loss of Co-pilot
  - Loss of Pilot and Co-pilot

JCA Vulnerability Analysis

- System-Level Vulnerability Analysis:
  - Pilot and Copilot are assessed as any other flight critical subsystem
  - Pilot and Copilot are modeled as being multiply vulnerable; either crew member can fly and land aircraft

- Three System Kill Levels:
  - Attrition: Incapacitation of both Pilot and Copilot in less than 30 seconds
    - Assess the probability of pilot and copilot being capable of performing job
    - Use ORCA Operational Casualty metric
    - Determine if pilot and copilot fall below the minimum performance level
    - Assign crew member a 1 (can perform job) or a 0 (can not perform job)
  - Fly and Land: Inability to fly and land
    - Flying time is vignette specific with time periods of 5, 15 or 30 minutes
    - Use ORCA Operational Casualty metric
  - Mission Abort: Any crew or troop member receives a MAIS ≥ 3
    - A MAIS ≥ 3 is a serious injury that requires immediate medical attention
    - Attrition supersedes mission abort if both Pilot and Copilot are incapacitated

Conclusion

- Analysis data was used to support the JCA's Full Rate Production Milestone Decision.

- Higher-resolution survivability assessments are available for measuring the value of improved air systems.

- ORCA is an invaluable toolset in answering the questions of how the individual person is directly tied into the overall air system.

Contact Information

Penny Willard 410-278-7233
penny.willard@arl.army.mil

Richard Moyers 410-278-4761
richard.moyers@arl.army.mil

U.S. Army Research Laboratory
Warfighter Survivability Branch (WSB)
Attn: RDRL-SLB-W
328 Hopkins Road
Aberdeen Proving Ground, MD 21005