



*TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.*  
A Process for Mapping Component Function  
to Mission Completion

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# Contact and Special Thanks



Kevin Agan  
Mechanical Engineer  
ARL/SLAD  
(410) 278-4458  
[Kevin.Agan@arl.army.mil](mailto:Kevin.Agan@arl.army.mil)

Special thanks to:  
Bill Landis  
Mechanical Engineer  
ARL/SLAD  
(410) 278-2675  
[Wlandis@arl.army.mil](mailto:Wlandis@arl.army.mil)

- Issue / Introduction
- Paradigm Preview
- A Required Tool: Fault Tree Analysis
- Paradigm Explanation
- The Mission and Means Framework
- Example: A simple tank battle
- Example: Networked UAV and SPH

A process is needed to evaluate the loss of component function in networked systems to the completion of the mission.

As a best practice, the consumer product industry has been conducting task-based component analysis for decades.

Mission:

- Task 1
- Task 2
- ⋮
- Task n

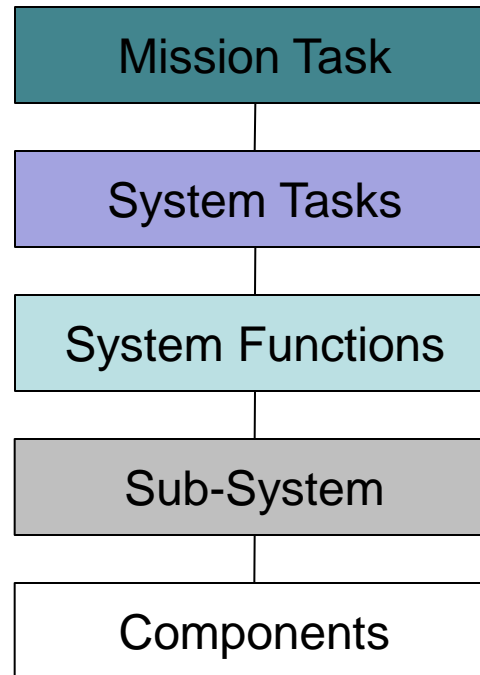
Functionality:

- Component 1
- Component 2
- ⋮
- Component n

A preliminary process has been developed within ARL/SLAD that can correlate component availability to the completion of Army standard mission tasks.

This process is currently being tested and improved.

- Using fundamentals from systems and reliability engineering:
  - Quantitatively define what the system and personnel can accomplish (tasks).
  - Quantitatively define what components are required to accomplish these tasks.
- Focus of analysis is remaining capability.
- Maintain terminology familiar to the military user:
  - Attainable Speed
  - Send/Receive Communications
  - Execute Fire Missions

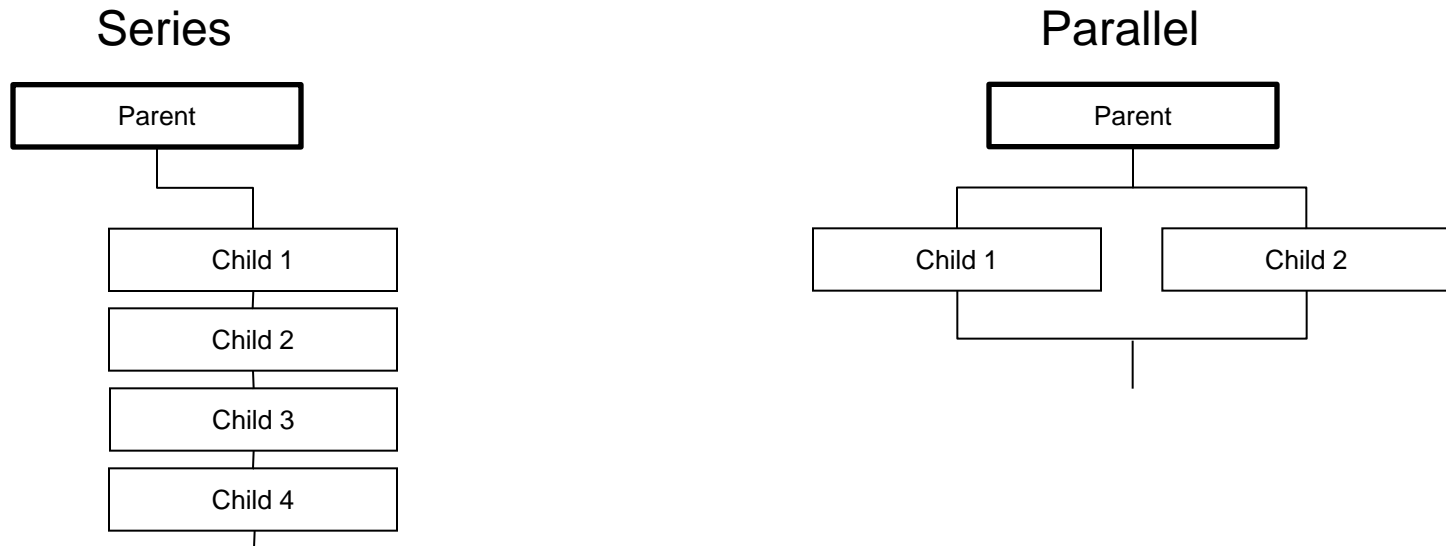




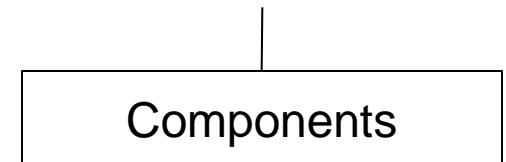
Fault Tree: a logic diagram that represents operating relationships.

As long as a functioning path can be traced from beginning to end, then the operation and/or capability is maintained.

Each level of the paradigm comprises of Fault Tree relationships to the level below.



- The component is the lowest level of the analysis.
- The component is the individual hardware that is required for a system to function.
  - Gear
  - Tire
  - Oil Filter
  - Fuel Tank

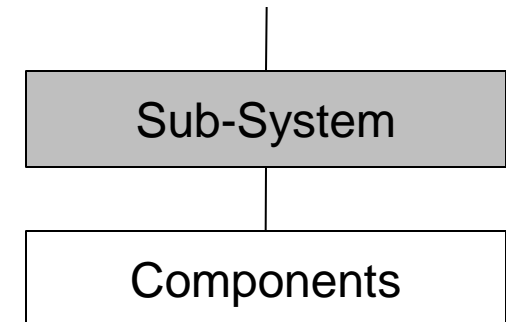
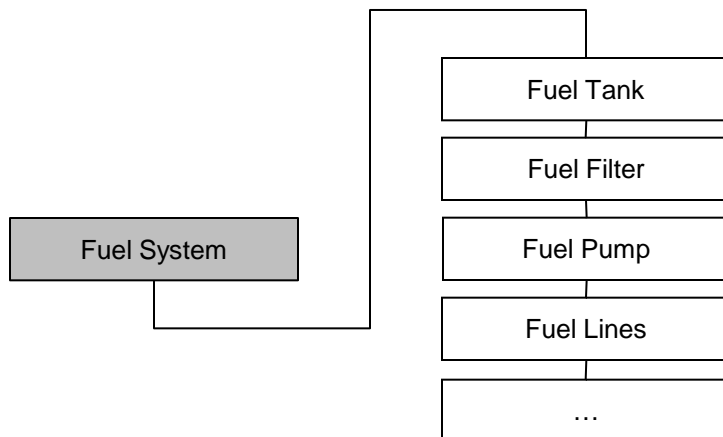


- For each component, failure modes and or operating conditions are defined.
  - Standard operating conditions
  - Probability of Component Dysfunction Given a Hit (PCD|H)  
{Probability of Kill ( $P_K$ )}
- Consider all modes and conditions with respect to successful operation given an insult or use.
- With an insult to a component, evaluate to see if it is available and functioning.

A Sub-System is an assembled collection of components that work together to fulfill a specific purpose.

Examples:

- Automatic Transmission
- Wheel, Front Left
- Lubrication System
- Fuel System



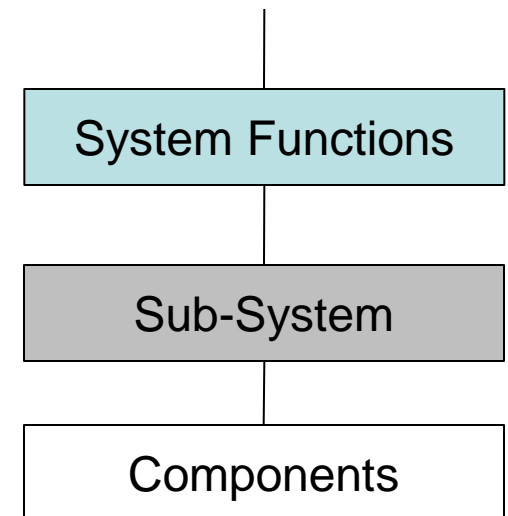
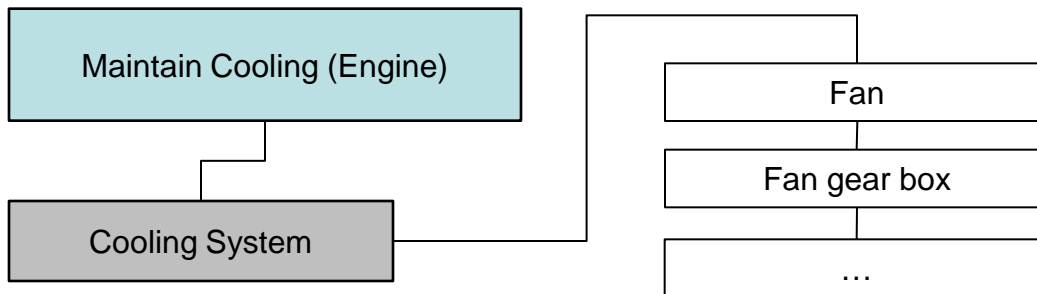
A System Function is an observable, repeatable, and measureable performance of the sub-systems.

## Examples:

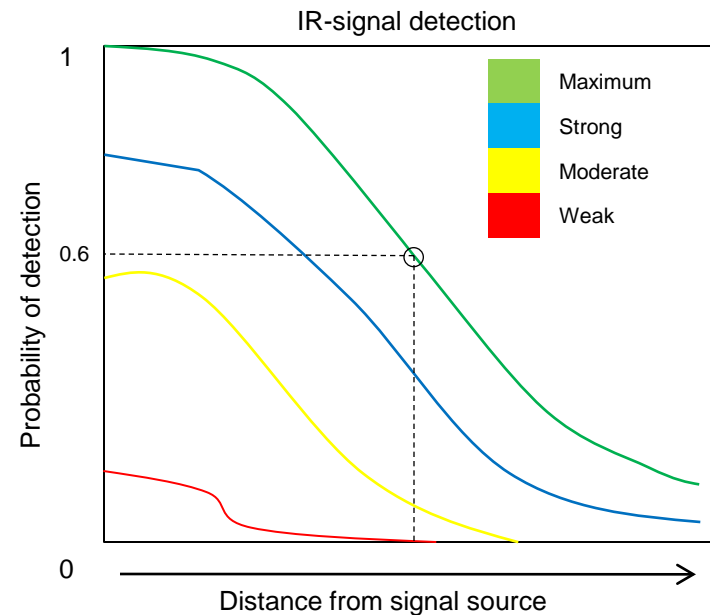
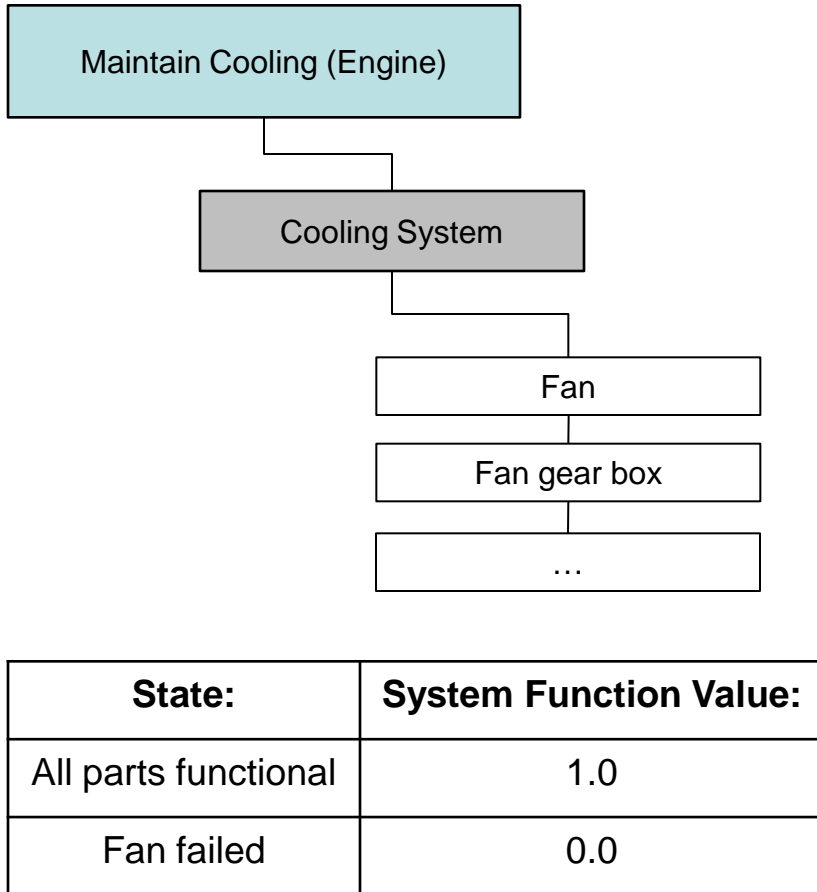
- Maintain Cooling (Engine)
- Generate Energy from Fuel
- Transmit Electrical Power
- Transfer Power to the Wheels

### Cooling sub-system example:

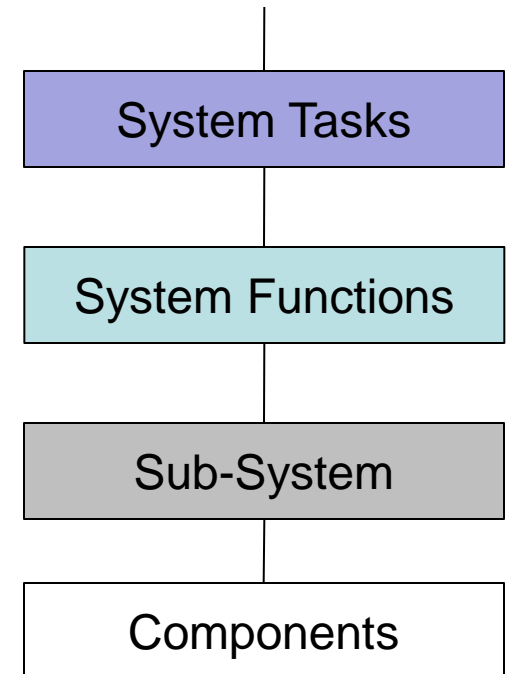
To maintain the proper operating temperature of the engine, the cooling system needs to remove waste heat from the system. The fans and related drive trains are required to maintain adequate air-flow.



System Functions can be either binary or probabilistic:



- A System Task is a mutually independent performance of the system.
  - This task is observable, measurable, and repeatable.
- For a light-duty four-wheeled vehicle, some sample System Tasks are:
  - Operate in night conditions
  - Travel off-road
  - Travel on-roads
  - Protect crew
  - Communicate short-range
  - Communicate long-range
  - Communicate intra-vehicle
  - Haul trailer



As damage is applied, a System Task could degrade into subsequent bins of performance, as seen below.

Travel on Roads	Damage state
Can travel 31 to 50 mph	Undamaged
Can travel 11 to 30 mph	Two flat tires, on run-flats
Can travel 1 to 10 mph	Four flat tires, on run-flats
NOT possible	Tires completely destroyed

Communicate short-range	Damage state
Data and voice	Undamaged
Data only	Hand-mike failed
Voice only	Radio computer failed
NOT possible	Radio failed

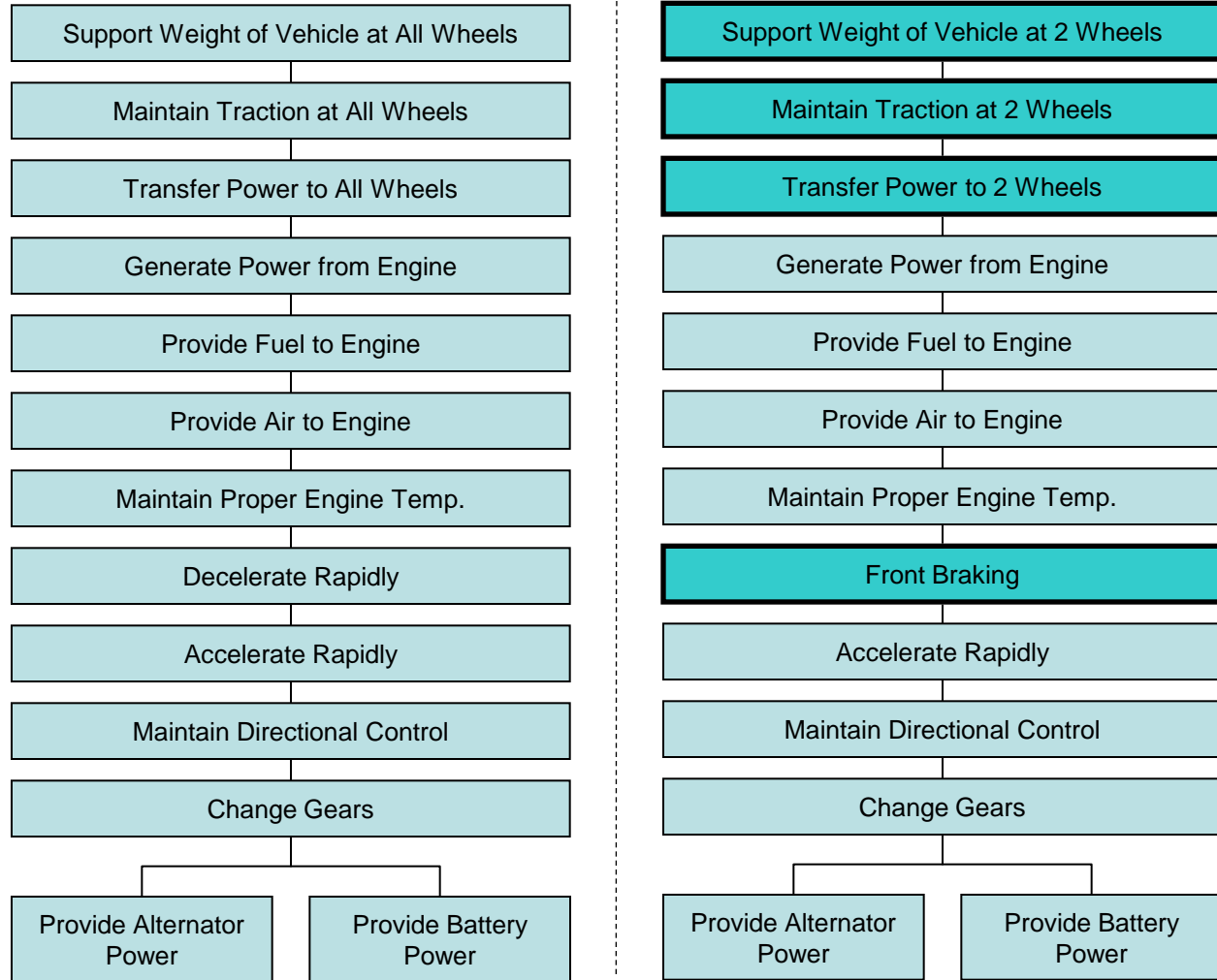
At any given time and damage state, a system will exist in only one of the bins.



Travel on Roads

Can travel 31 to 50 mph

Can travel 11 to 30 mph

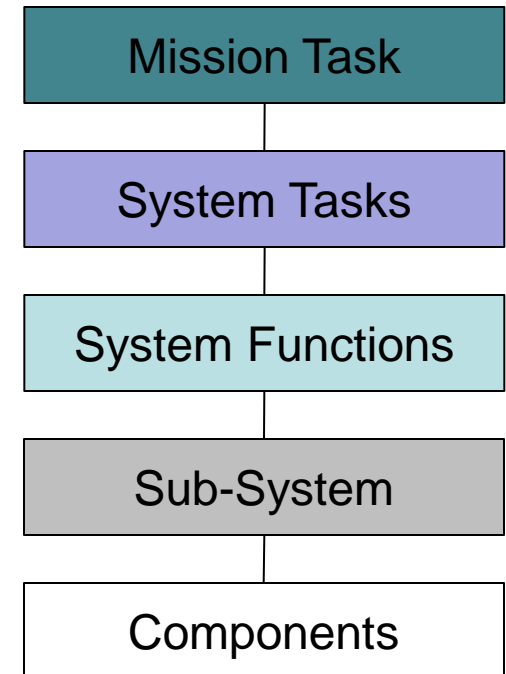


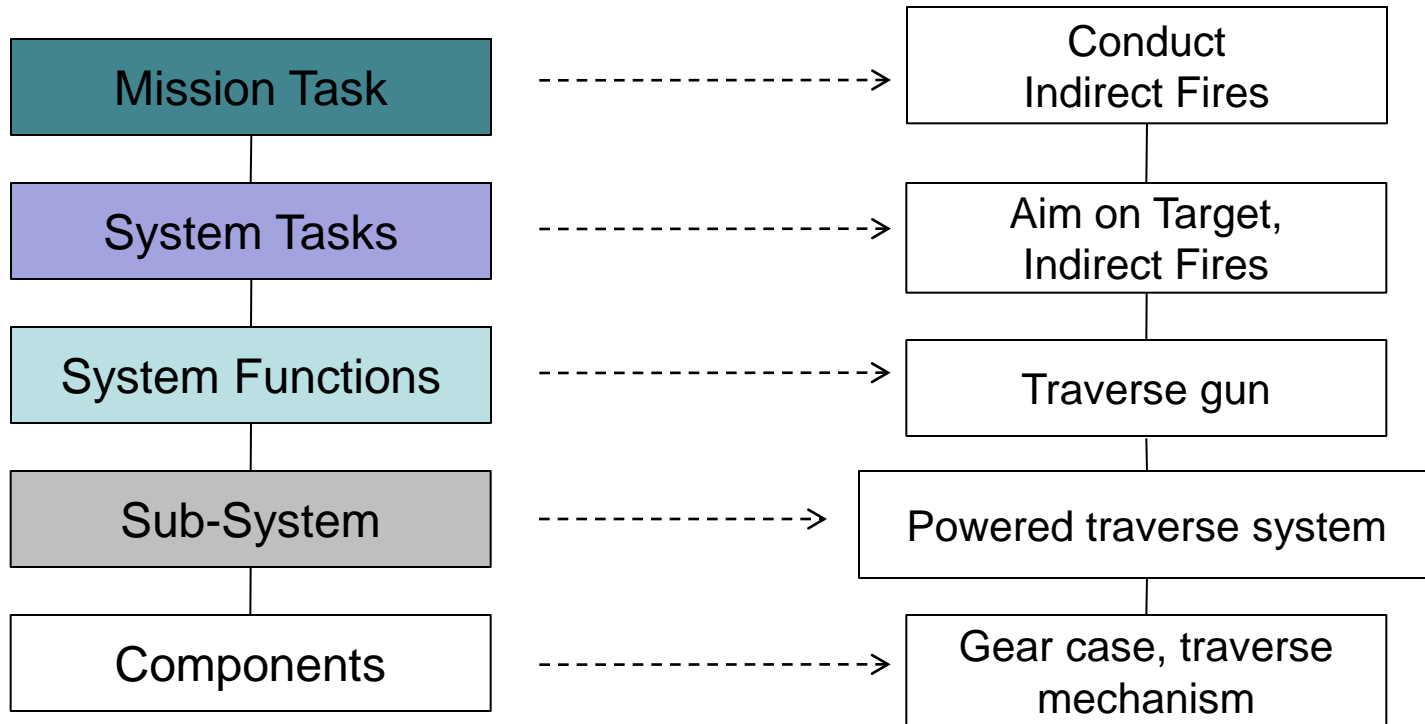
A Mission Task is the operational task that is to be executed by the soldiers and systems working in concert.

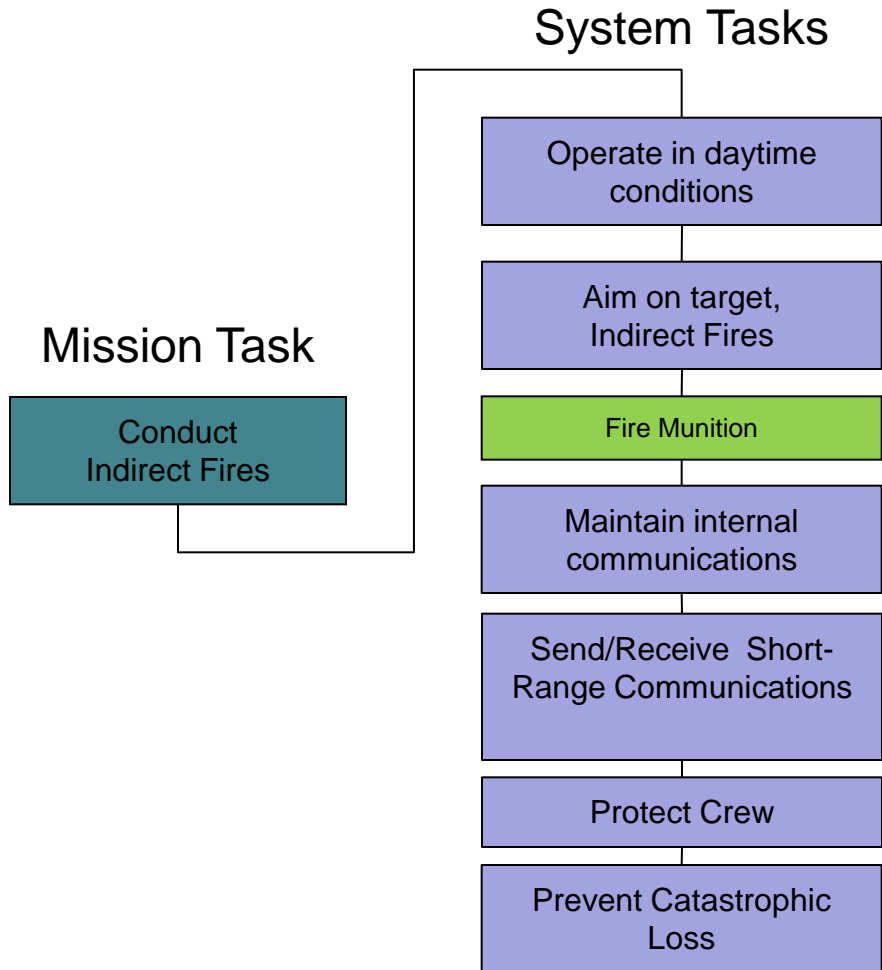
- For the Army, the Mission Tasks are defined in Field Manual (FM) 7-15 “The Army Universal Task List” (AUTL).

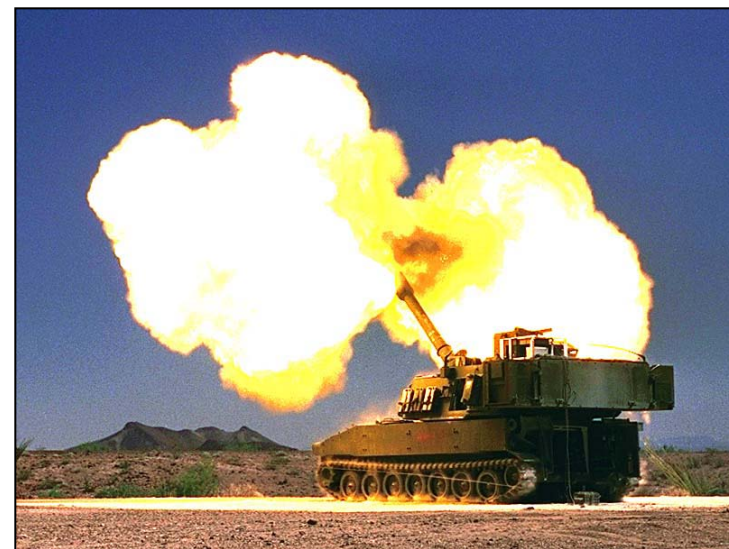
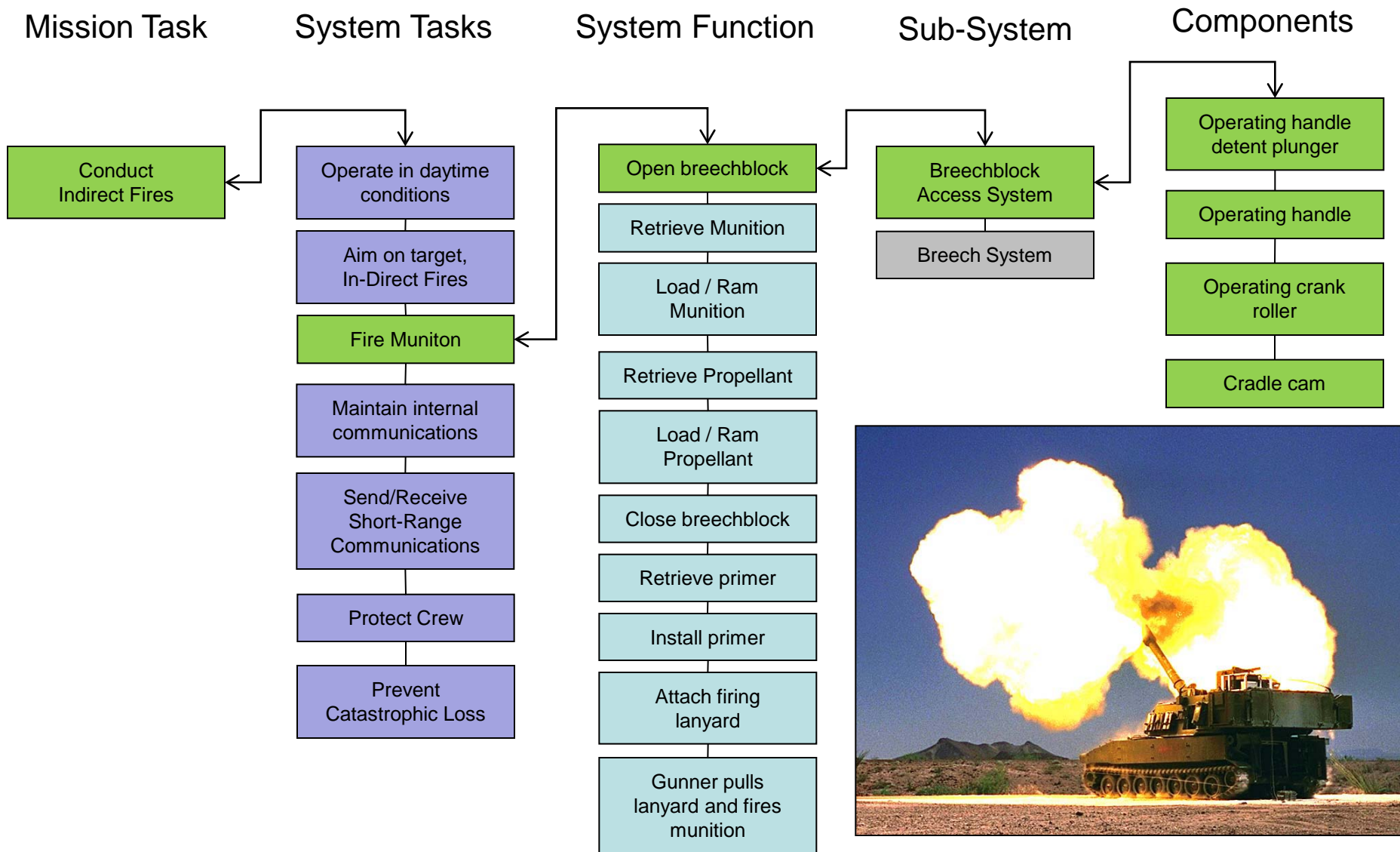
Examples of Mission Tasks:

- Conduct a raid
- Conduct direct fires
- Hold an objective

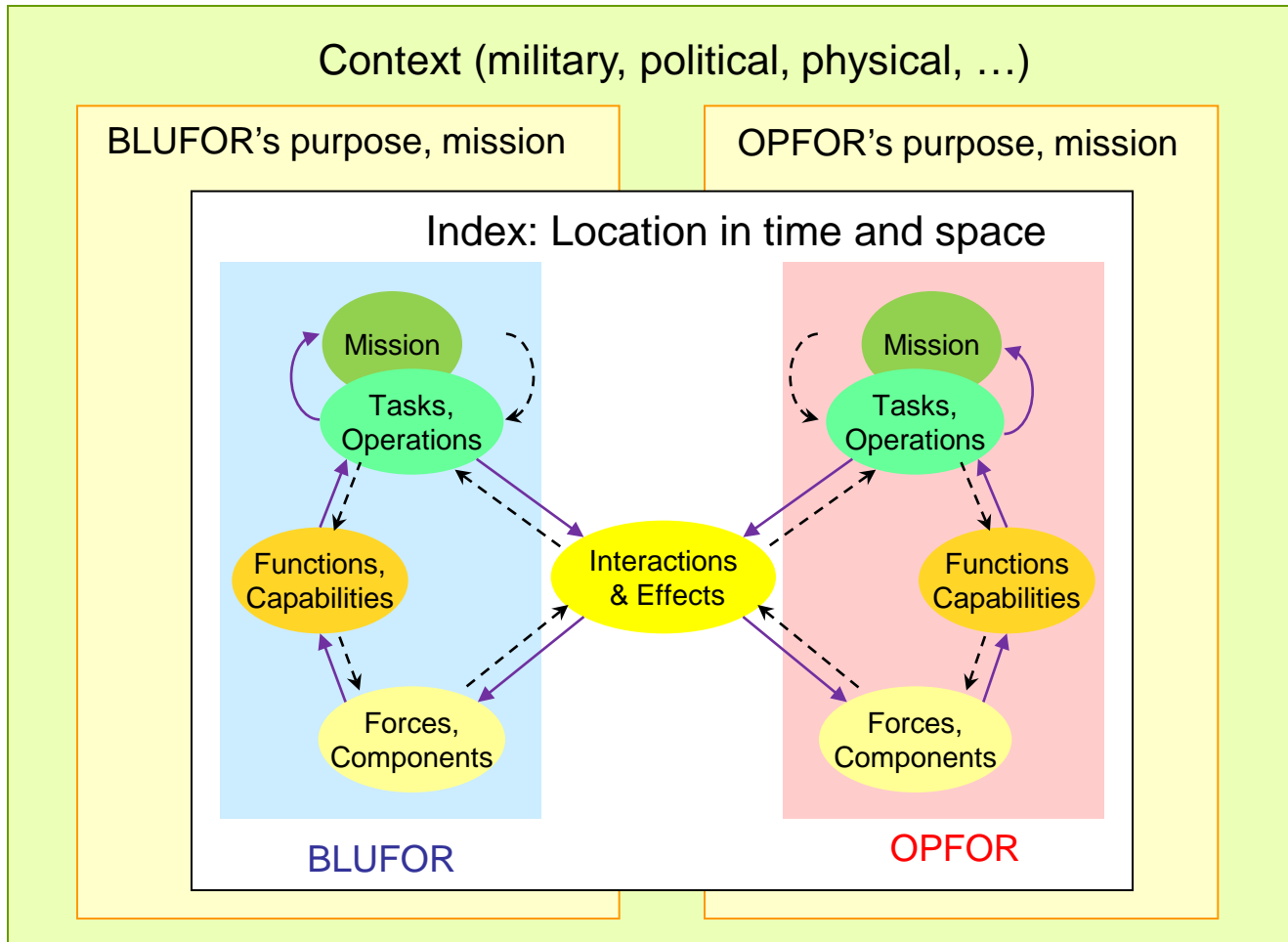






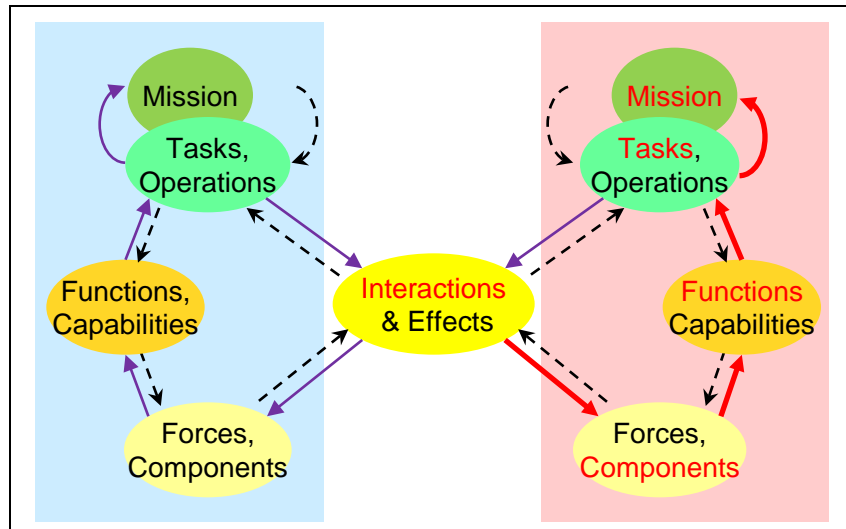
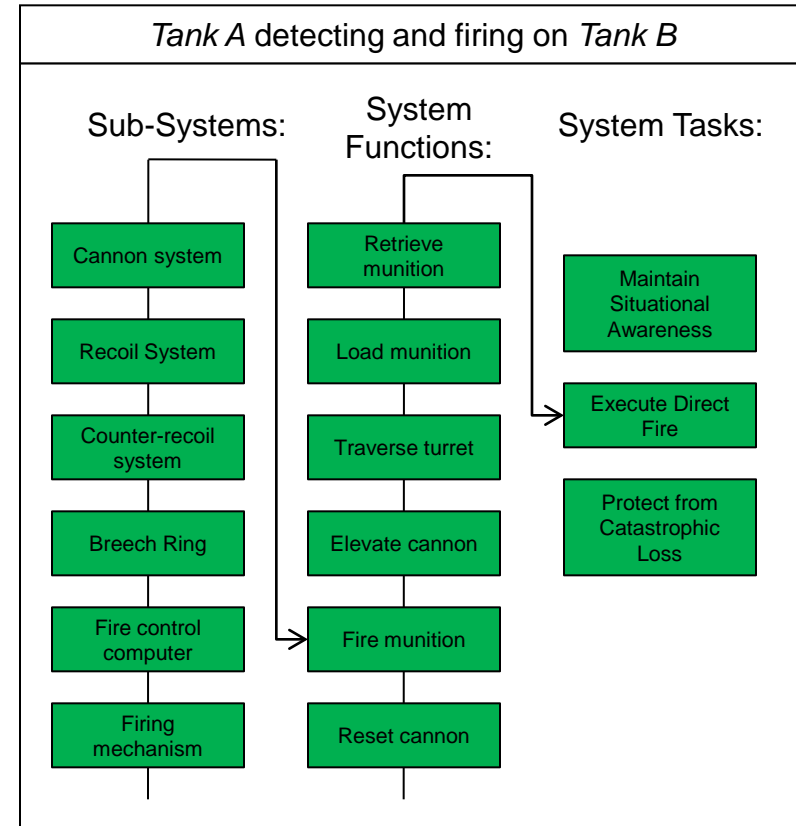


- This example will look at a simplified hypothetical engagement.



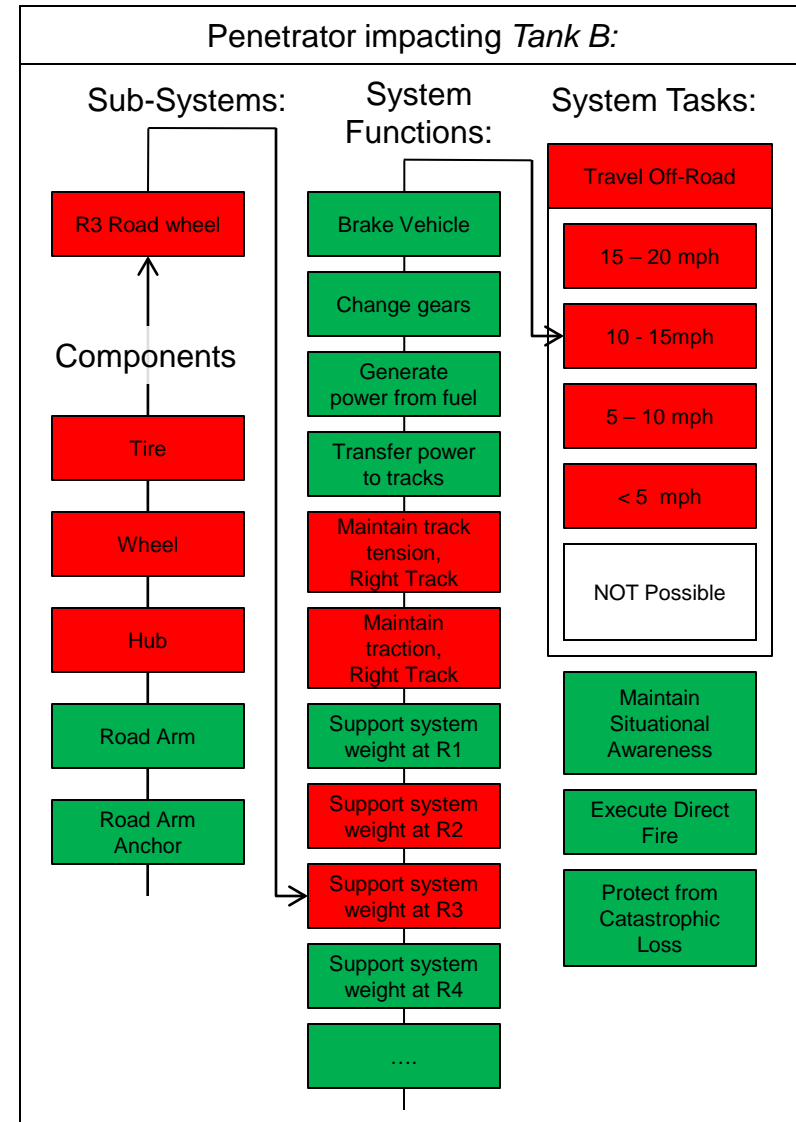
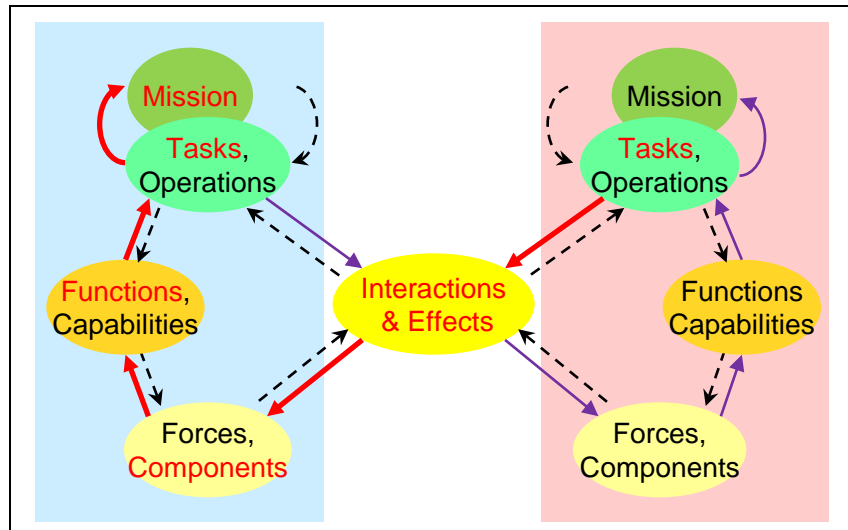
Source:  
 "Fundamentals of Ground Combat System Ballistic Vulnerability / Lethality"; Dietz, et. al., pg 14

- *Tank A* (OPFOR) observes *Tank B* (BLUFOR) move into effective range.
  - All *Tank A* components are functional
  - The system can accomplish the “*Execute Direct Fire*” System Task
- An anti-tank round is fired.



The round fired from *Tank A* impacts *Tank B* on the track and road wheels.

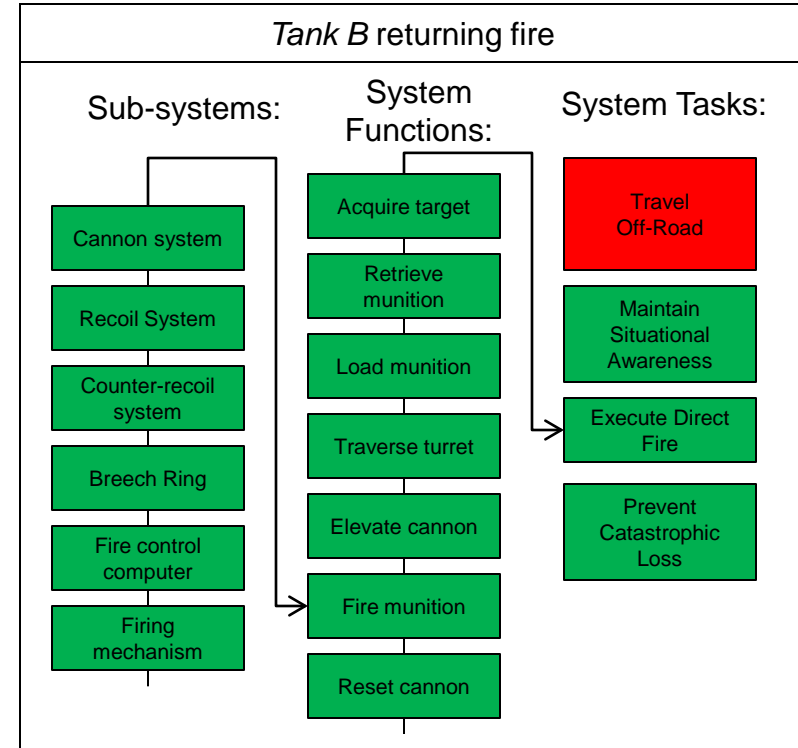
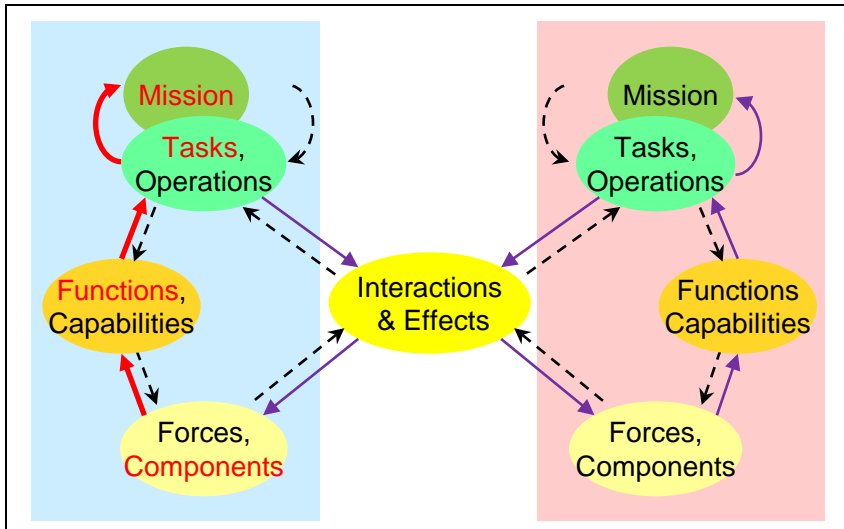
- The interaction of the round with the track, road wheels, and suspension will cause those components to fail.
- The only resultant capability for “*Travel Off-Road*” is “NOT possible.”





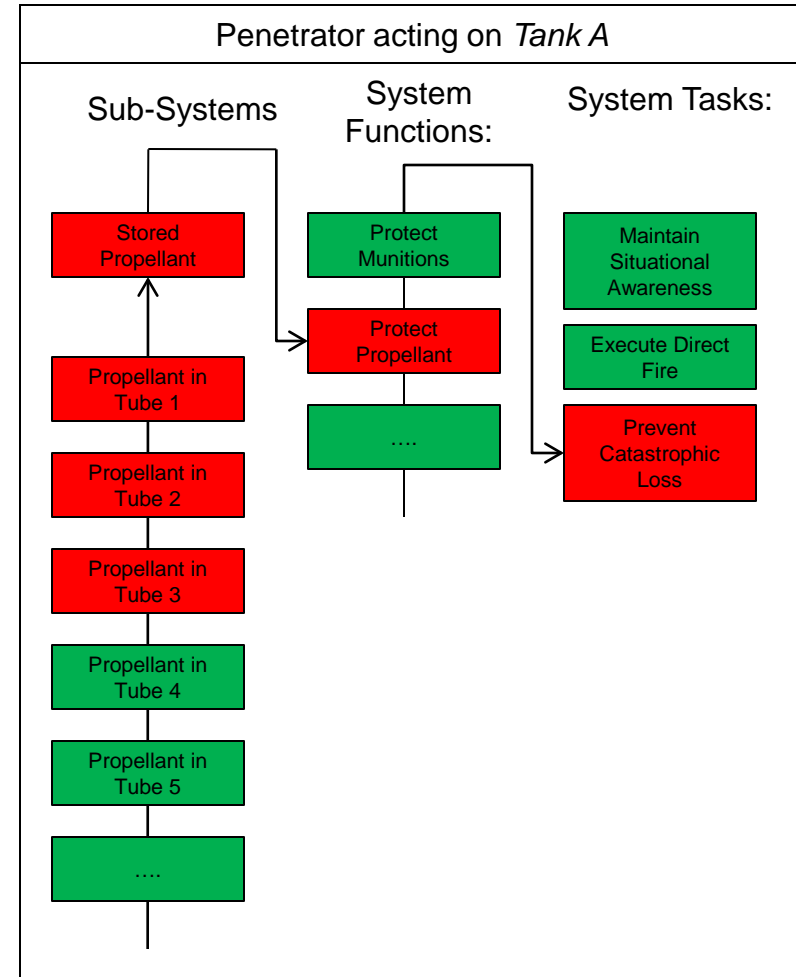
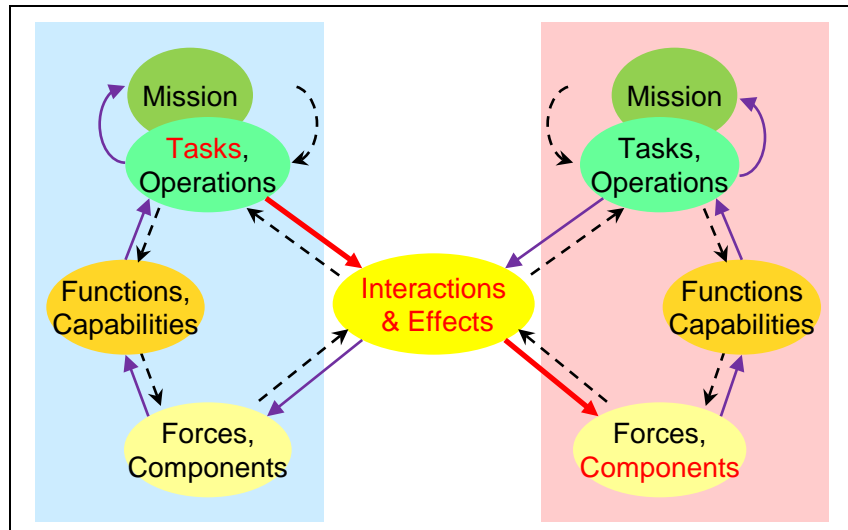
## Tank B returns fire on Tank A.

- All firepower components are functional.
- Capable of all Firepower System Tasks.



The round from *Tank B* impacts the side of *Tank A*.

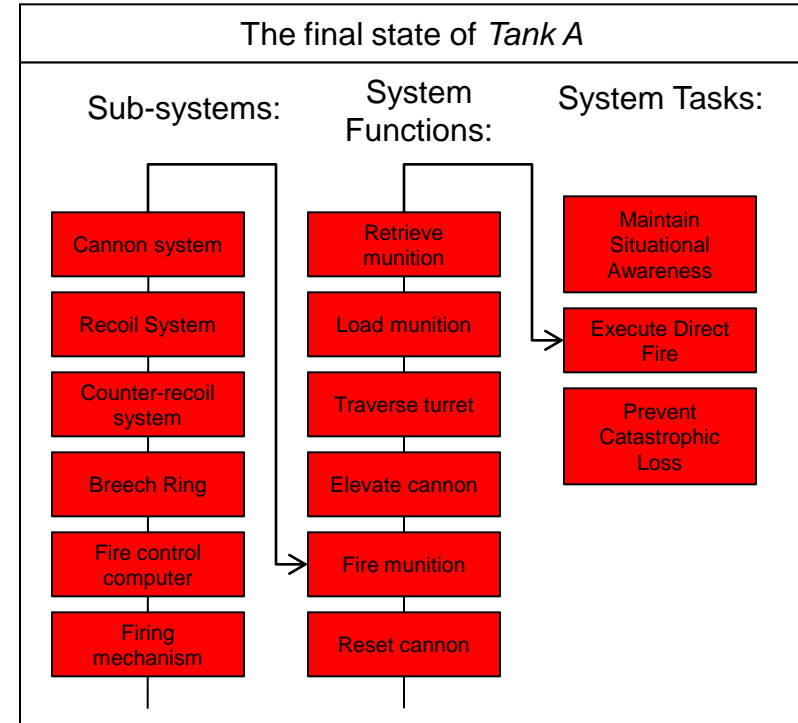
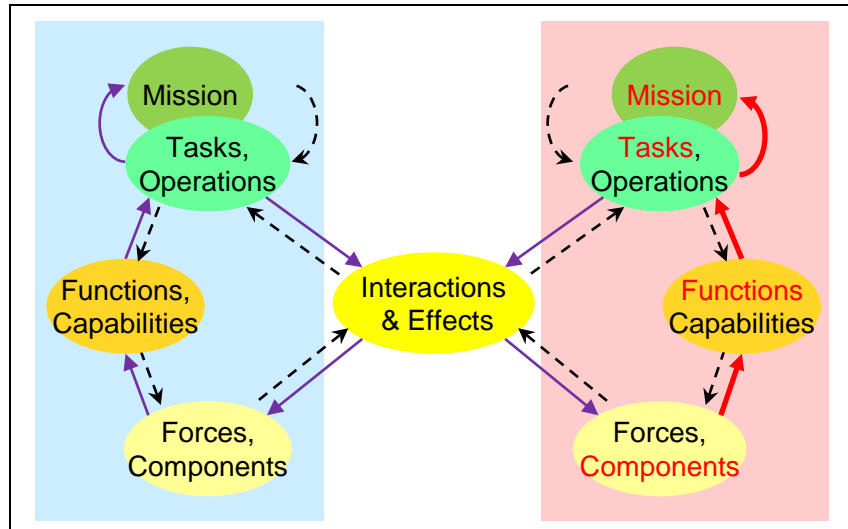
- The penetrator from the *Tank B* passes through the armor of the *Tank A*.
- Upon entering the interior, either spall or the main penetrator interact with energetic material.
- This interaction results in a catastrophic detonation.



*Tank A* has experienced a catastrophic event.

Due to the loss of all components:

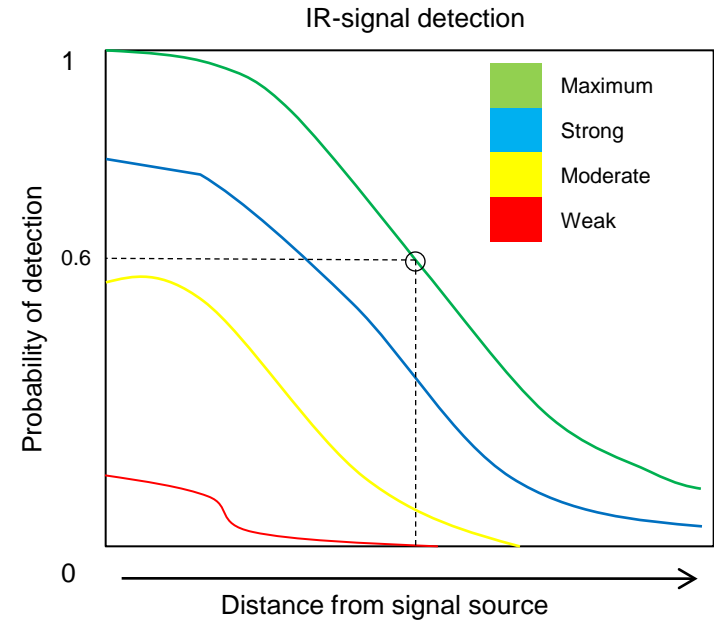
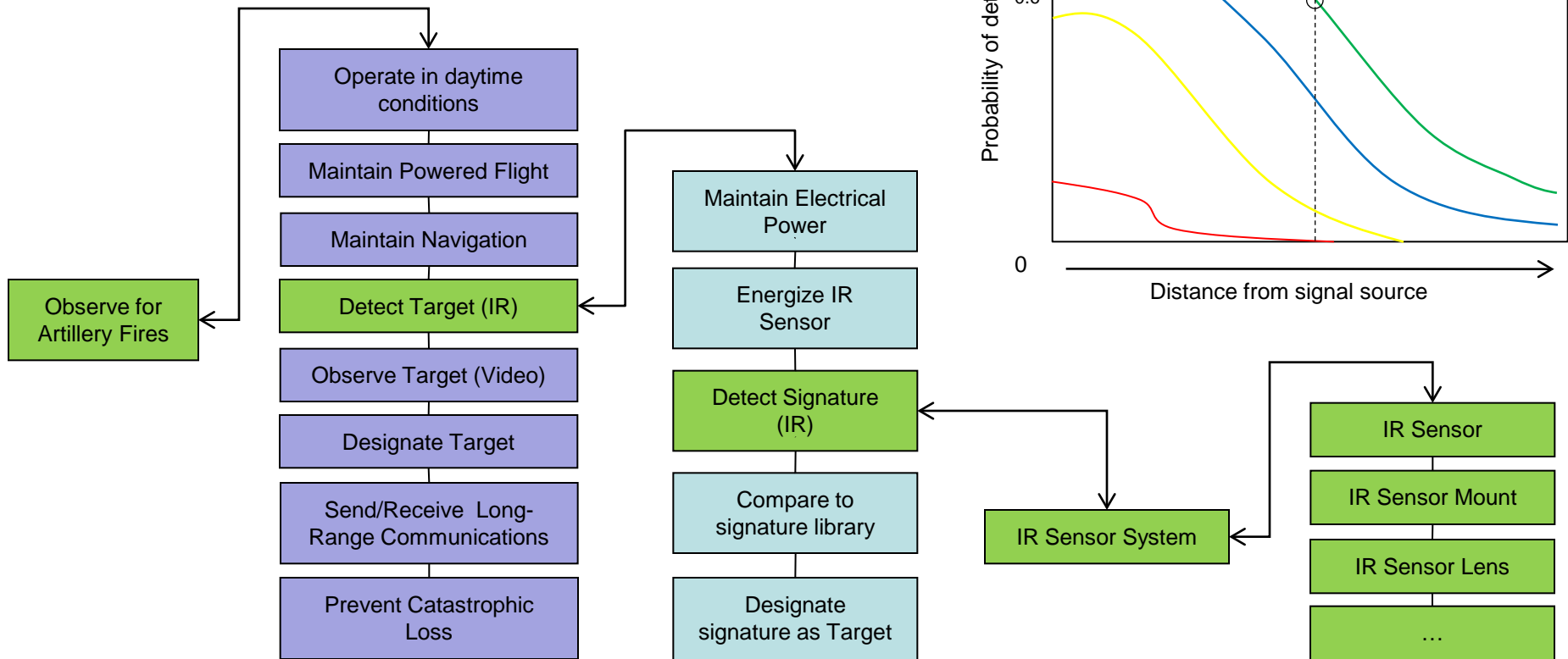
- all *Tank A* System Functions are not available,
- all *Tank A* System Tasks are not available,
- the *Tank A* Mission Tasks cannot be completed.



In a future combat scenario, an unmanned aerial vehicle (UAV) functions as a forward observer for a self-propelled howitzer (SPH).



The UAV, while on patrol, flies within detection range of a possible target emitting IR radiation.



Mission Task

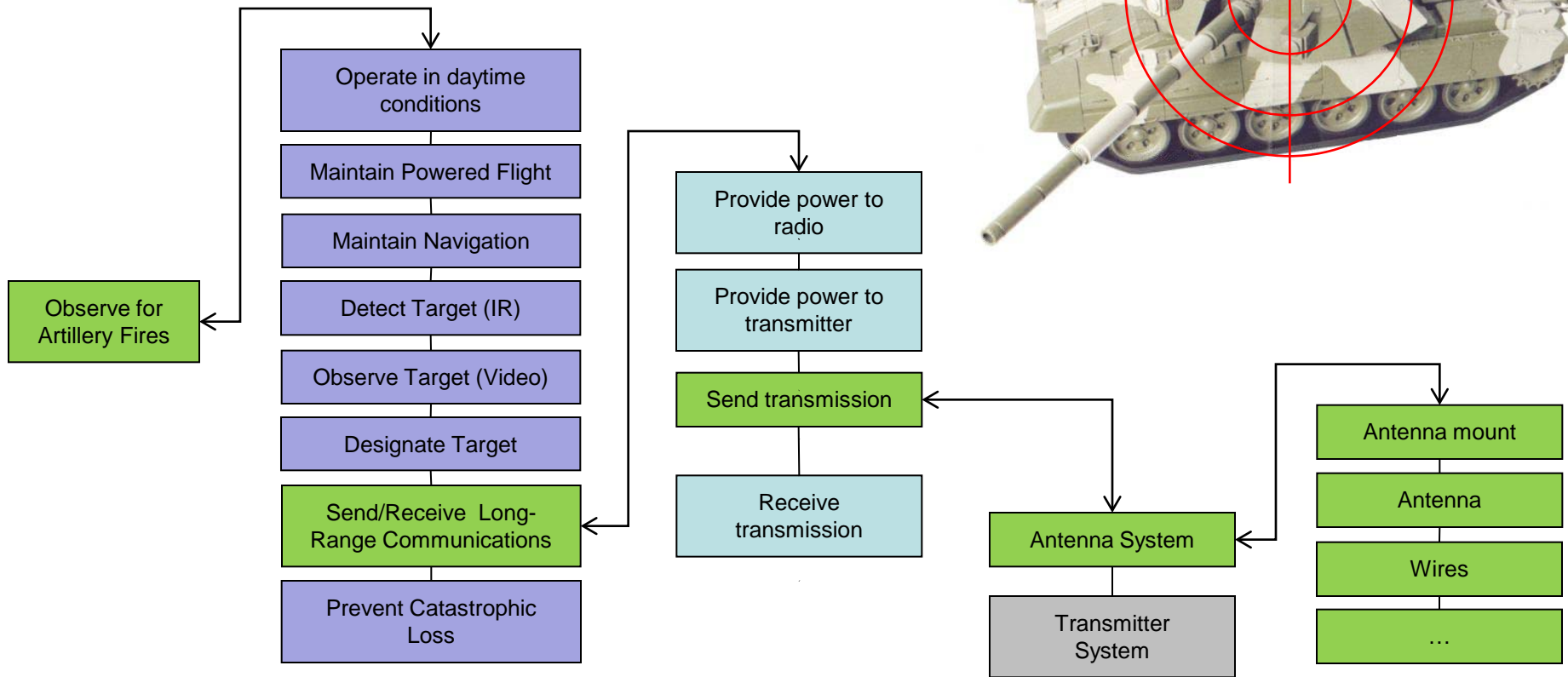
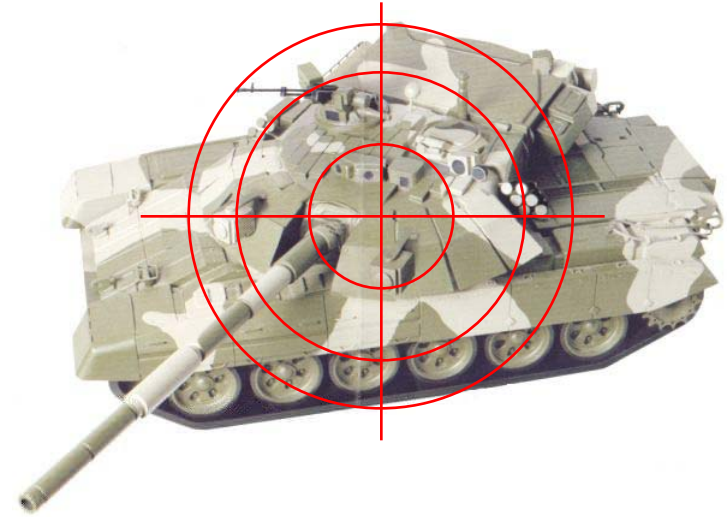
System Tasks

System Function

Sub-System

Components

Because the UAV detected the target, it will send a communication to the emplaced SPH.



Mission Task

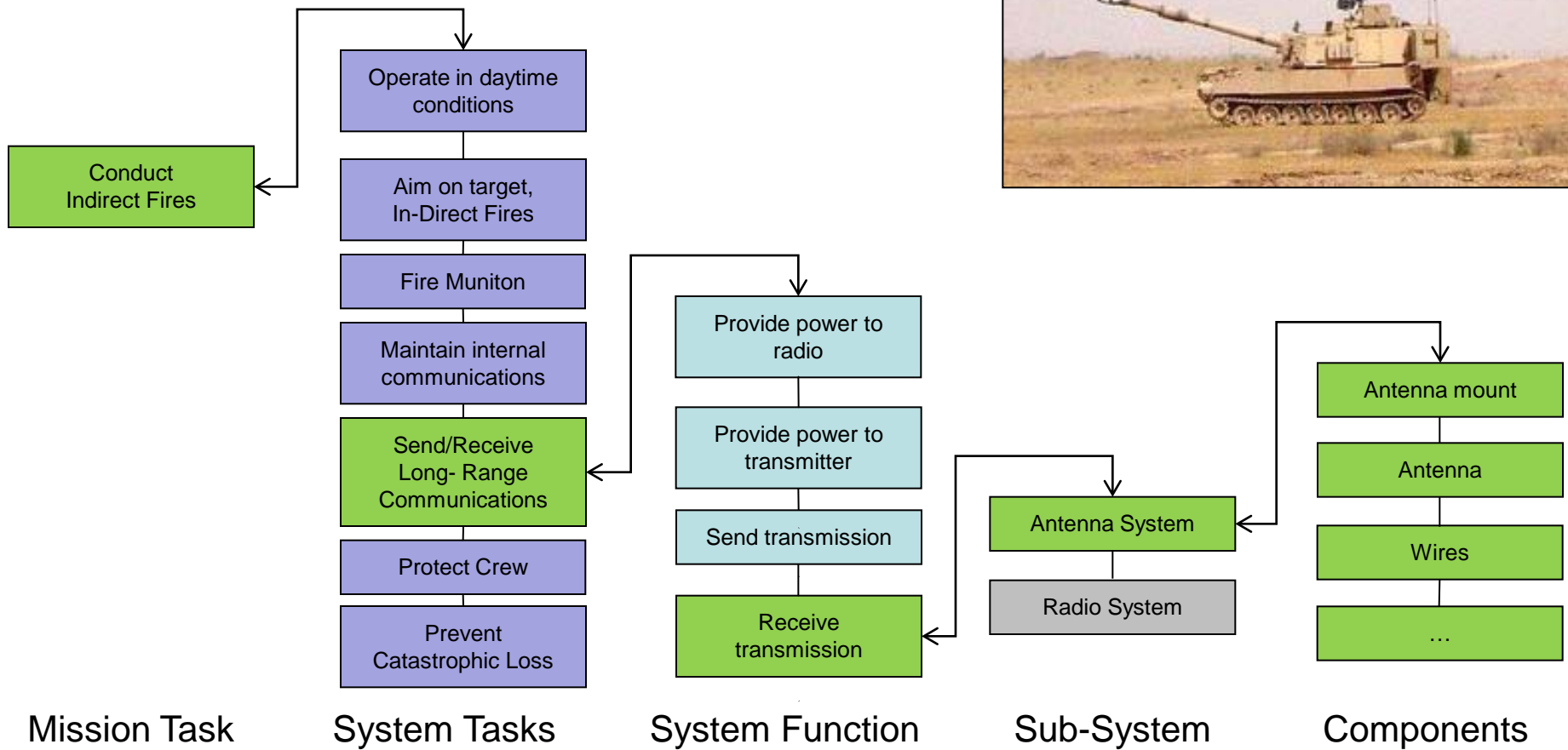
System Tasks

System Function

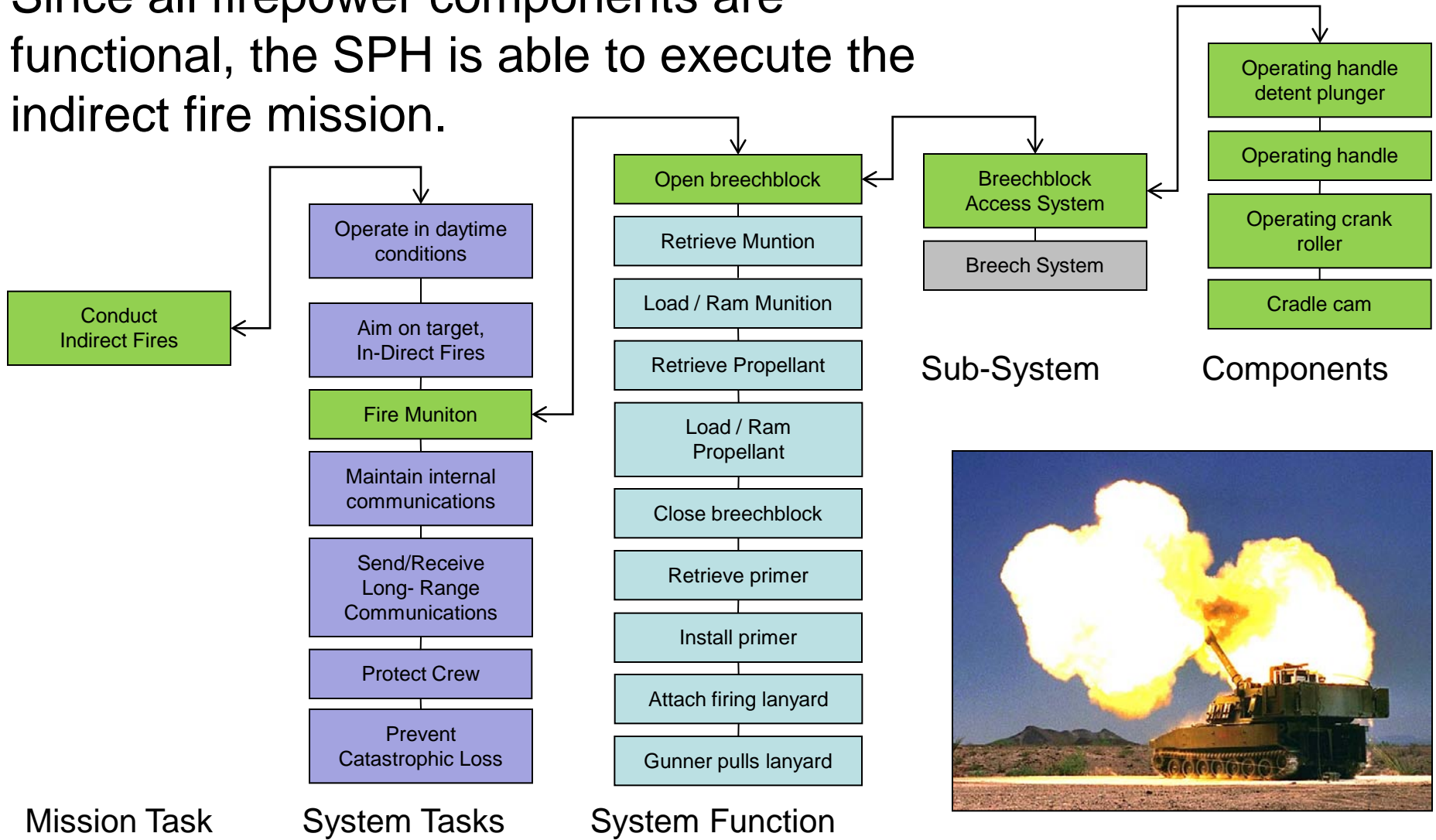
Sub-System

Components

Since all communication components are functional, the SPH is able to receive the fire mission.



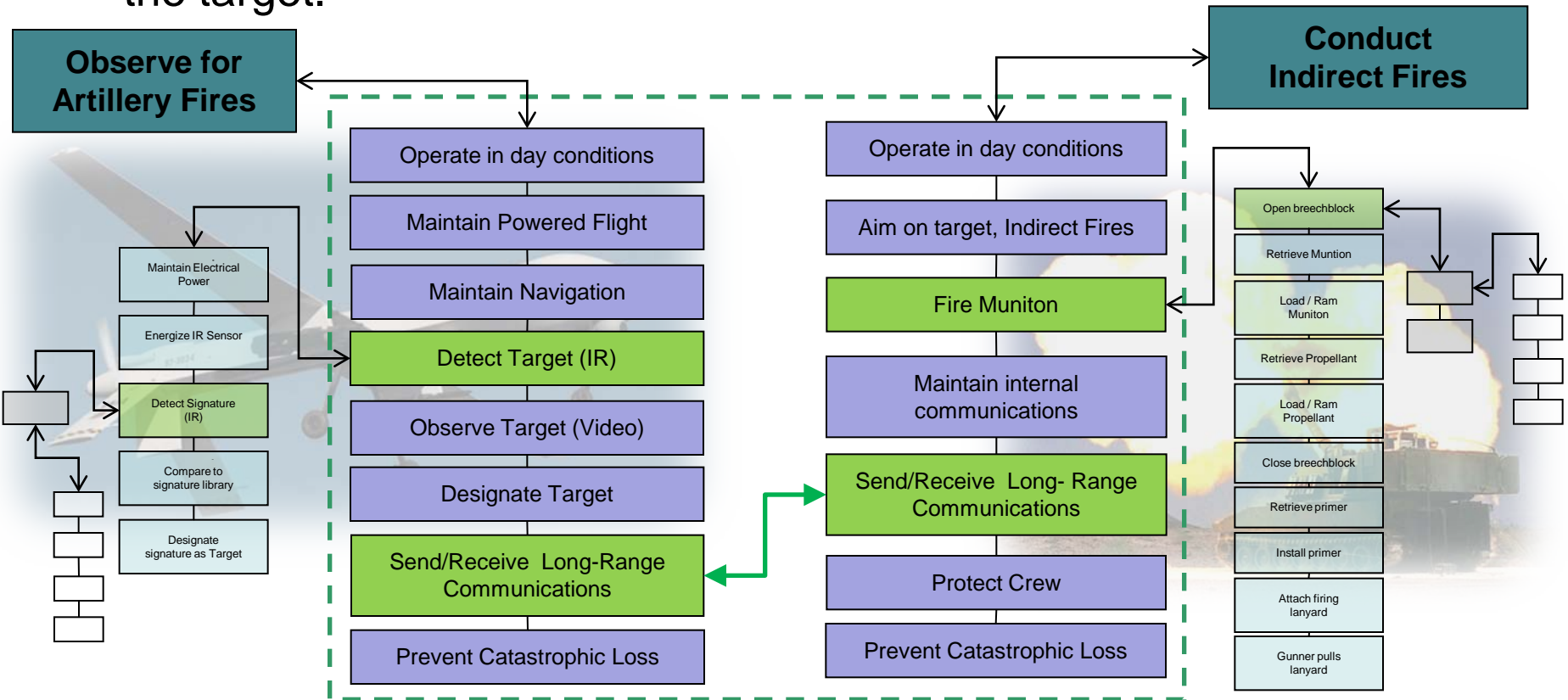
Since all firepower components are functional, the SPH is able to execute the indirect fire mission.





Connect systems by mutual System Tasks.

- As the UAV detected the target, it was able to send the information to the SPH.
- As the SPH was able to receive communications, it was able to fire on the target.



- Traditionally, V/L analysis has focused on single vehicle vulnerability.
  - Example: Firepower Loss of Function (F LoF) = 0.7
  - Mission context averaged across all missions.
- The presented process:
  - Mission context is maintained.
  - The single vehicle is now assessed for remaining capability.
  - Reports ability to complete tasks.
  - Reports ability to complete mission.
- By quantitatively defining a system's functionality and linking to descriptive tasks, we are able to link independent systems and evaluate the impact to the mission.