11th ICCRTS

COALITION COMMAND AND CONTROL
IN THE NETWORKED ERA

Multi-mission Prioritization Using Cost-based Mission Scheduling

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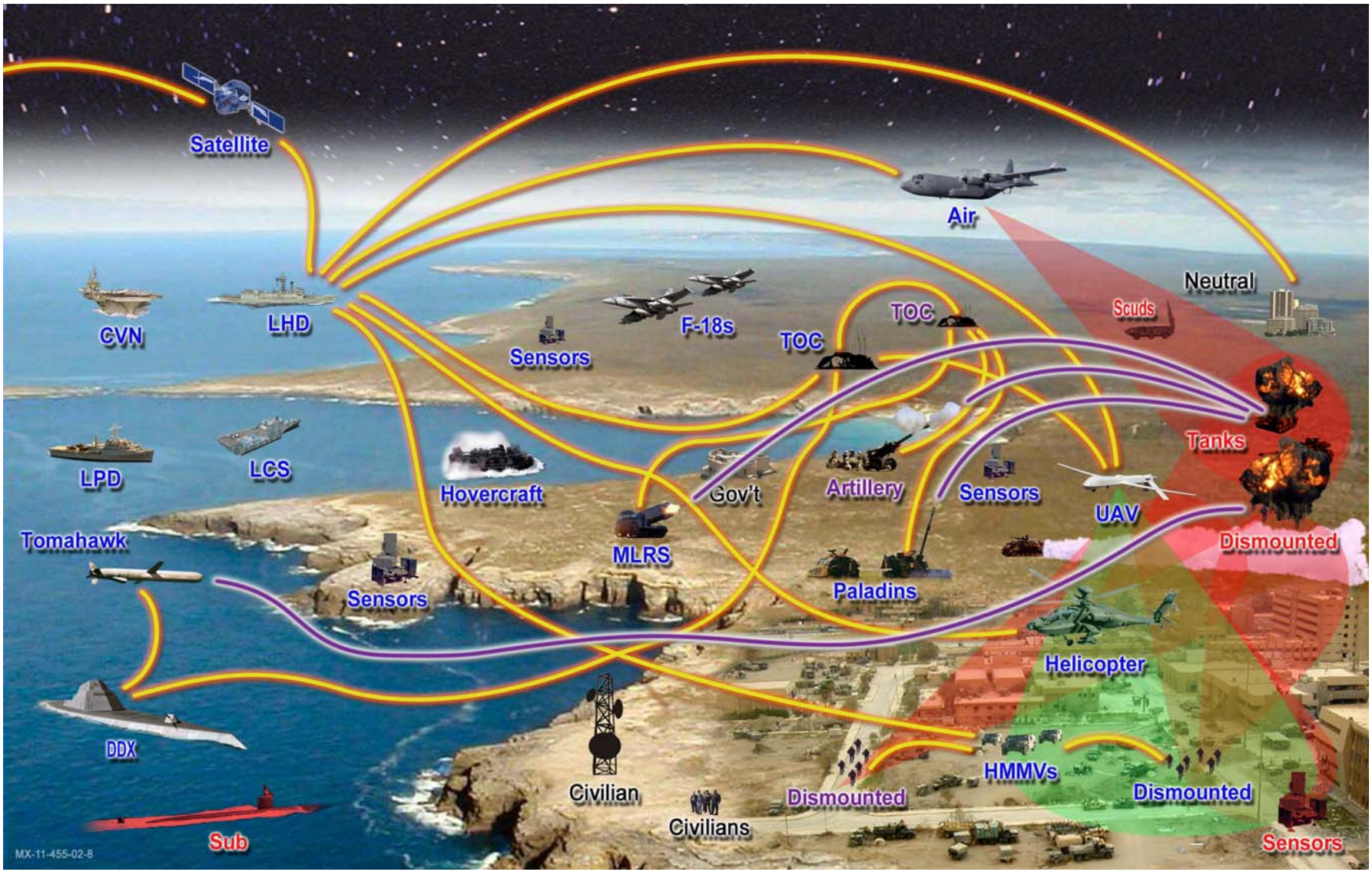
Presentation Overview

- Motivation
- Scheduling in the Command and Control Domain
- Incorporating Cost into the Mission Schedule
- Anatomy of a Cost-based Scheduling Algorithm
- Next Steps
- Summary

Motivation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MLRS
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Helicopter
DDX
HMMVs
Civilian
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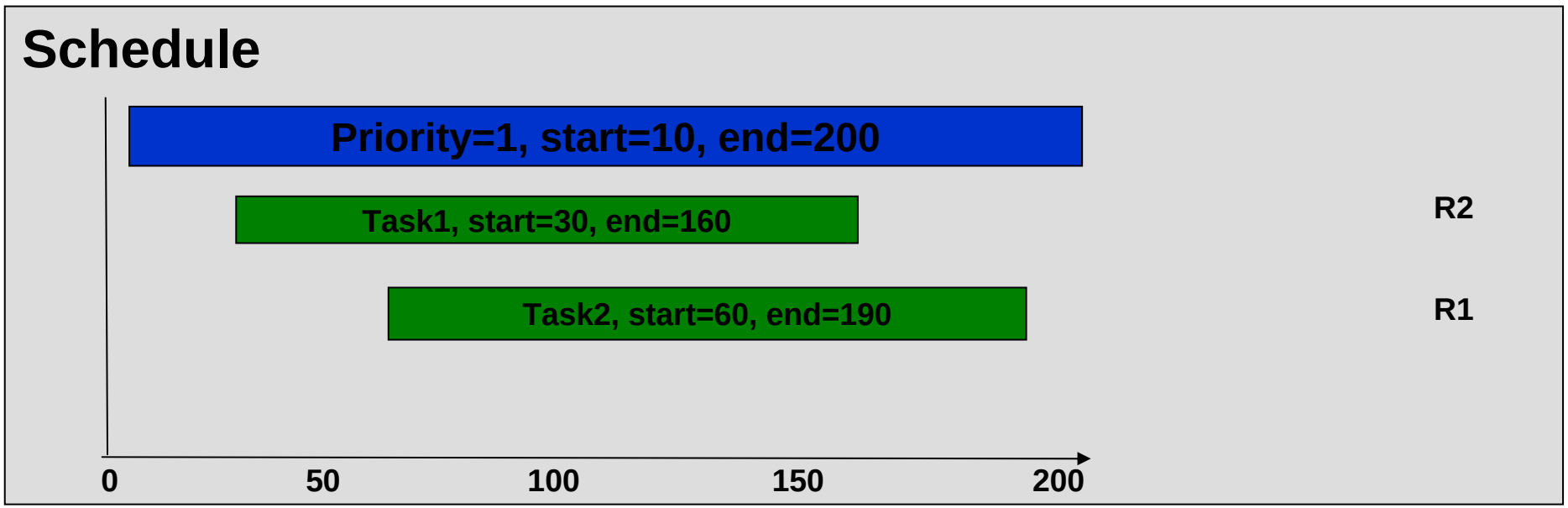
Motivation

- Command and Control (C2) is complex in a net-centric environment
- One node may support more than one command node
- Mission objectives may differ per command node
- Need to prioritize across mission objectives

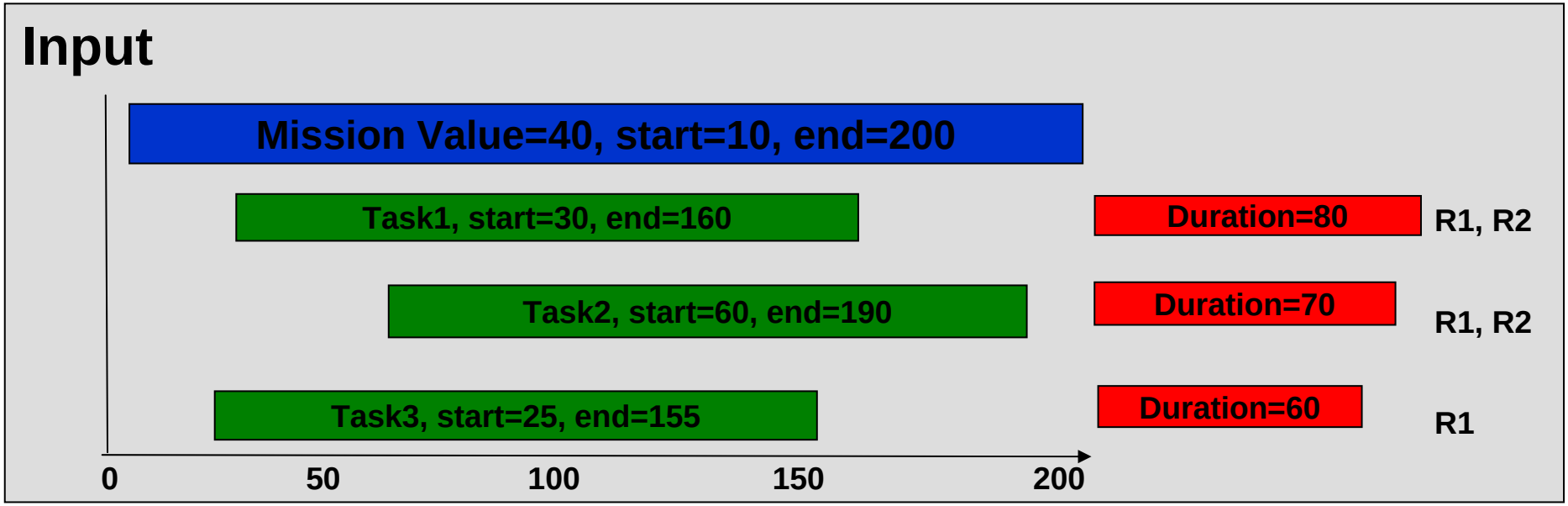
Scheduling in the Command and Control Domain – Static Scheduling

- Missions scheduled based on a time window
- Missions are static once placed on the schedule
- Resource contention resolved using priority

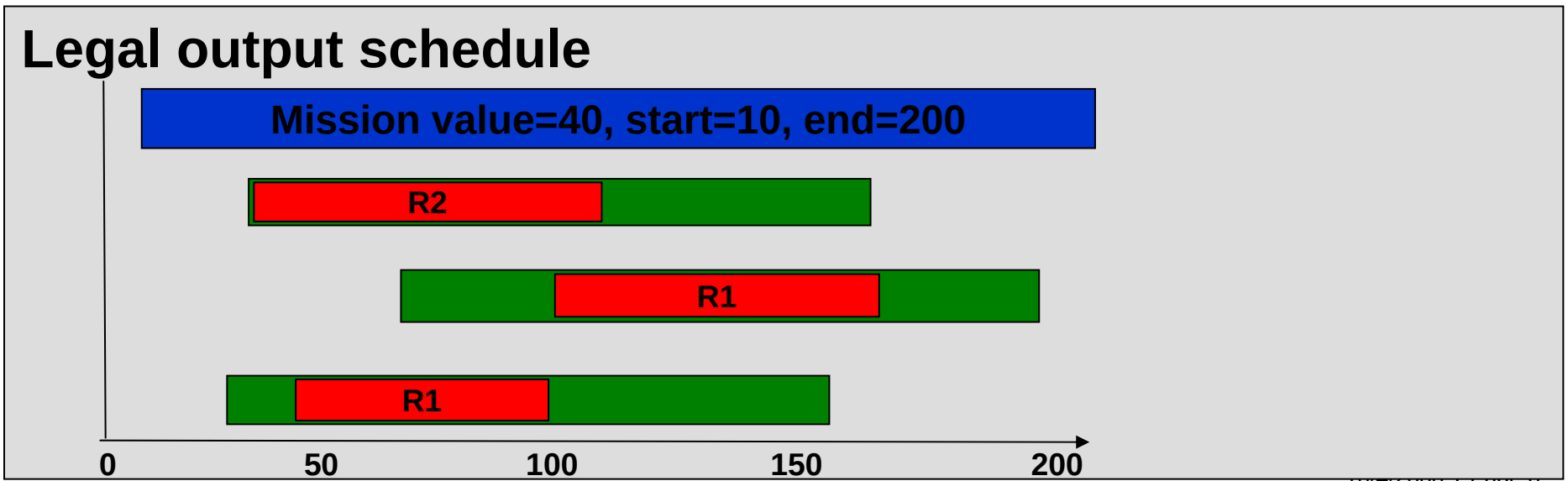


Scheduling in the Command and Control Domain – Dynamic Scheduling

Input



Legal output schedule

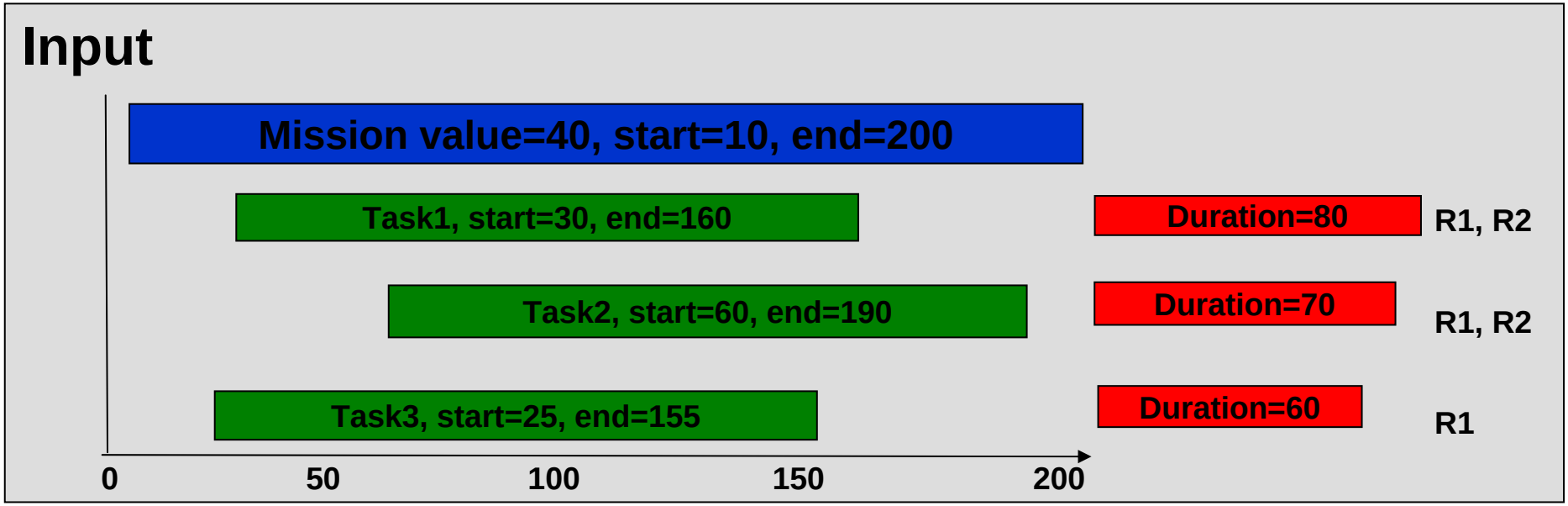


Scheduling in the Command and Control Domain – Dynamic Scheduling

- Missions scheduled based on time window
  - Delegates more control to scheduler while meeting mission goals
  - Larger window allows scheduler greater flexibility
  - Time window sent to lower-level schedulers or domain controllers
- Each task has a duration less than or equal to the time window
- Missions are dynamic once on the mission schedule
  - Scheduler moves allocation within time constraints
- Resource contention resolved via priority scheme

Scheduling in the Command and Control Domain – Dynamic Scheduling

Input



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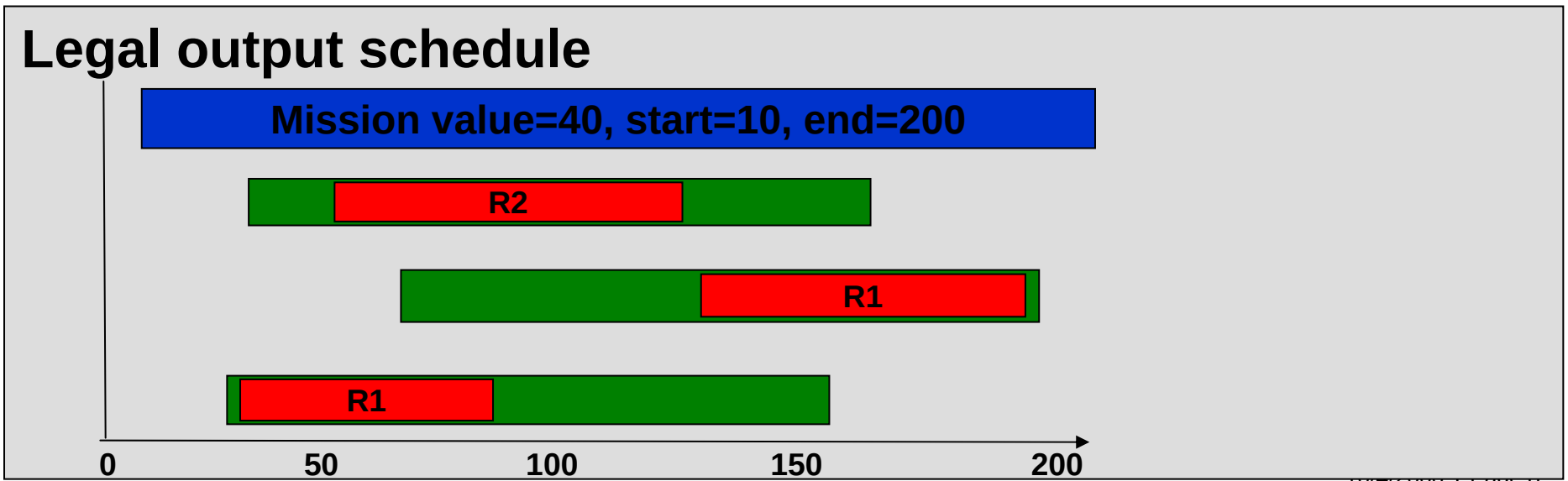


Survivability

- Survivability as defined for a Navy ship is:

  *Survivability = 1 – (Susceptability * Vulnerability * Restoration)*

  Where:
  - Susceptibility is the ability to ***Avoid***
    - Susceptibility = (Probability of attack given an encounter * Probability of hit given an encounter)
  - Vulnerability is the ability to ***Withstand***
    - *Vulnerability = Probability of kill given a hit*
  - Restoration is the ability to ***Restore*** vital systems
    - Restoration = Probability of restoration given a hit.

Survivability is the ability to achieve mission goals

What is Cost?

- Based on the Survivability equation we can surmise:

  Cost = (1 – Survivability) X 100

Thus:

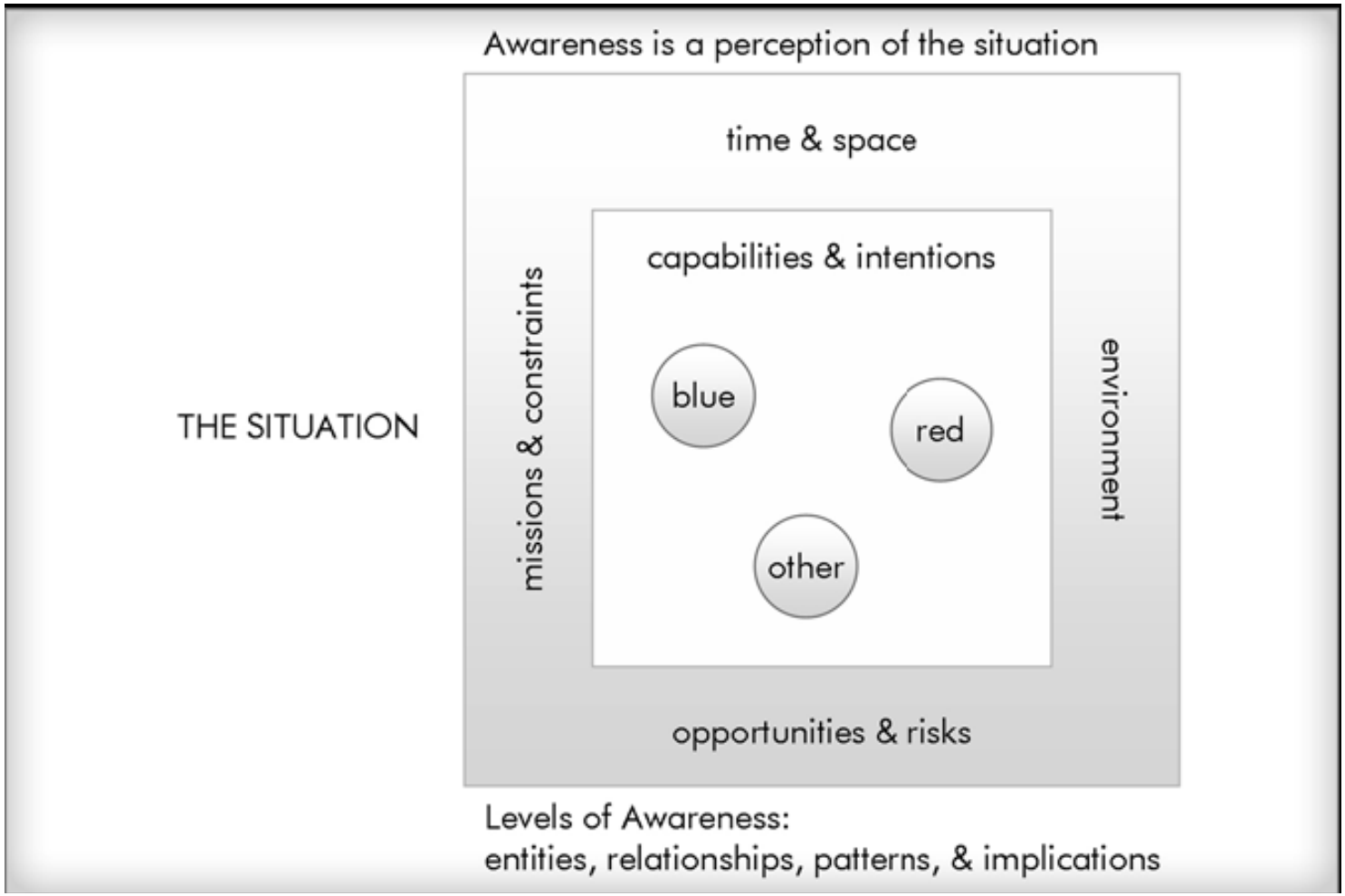
- Cost is a numeric representation of the cost to ownship if a threat is realized
- Cost has a range of 0-100
  - A zero cost is optimal
  - A cost of 100 indicates the ship cannot fulfill its mission
- Cost aids in multi-mission prioritization
  - Priority in one mission area may not be the same in another mission area
  - Cost provides a single means to relate all mission areas to the ability of the ship to achieve its overall mission

Cost enables multi-mission prioritization

Cost as it Relates to Mission Value

- Mission Value provides the overall rank or priority of a mission
- Mission Value has three components:
  - Cost
    - Cost to ownship if a threat is realized
  - Time to Go (Tgo)
    - Remaining time that a threat is actionable
  - Threat Priority
    - Priority given in a single mission area
- Weighting values may be used to allow one component to be given more weight in the computed Mission Value

Incorporating Cost into the Mission Schedule



THE FUTURE OF COMMAND AND CONTROL: *UNDERSTANDING* COMMAND AND CONTROL, David S. Alberts and Richard E. Hayes, CCRP Publication Series, 2006

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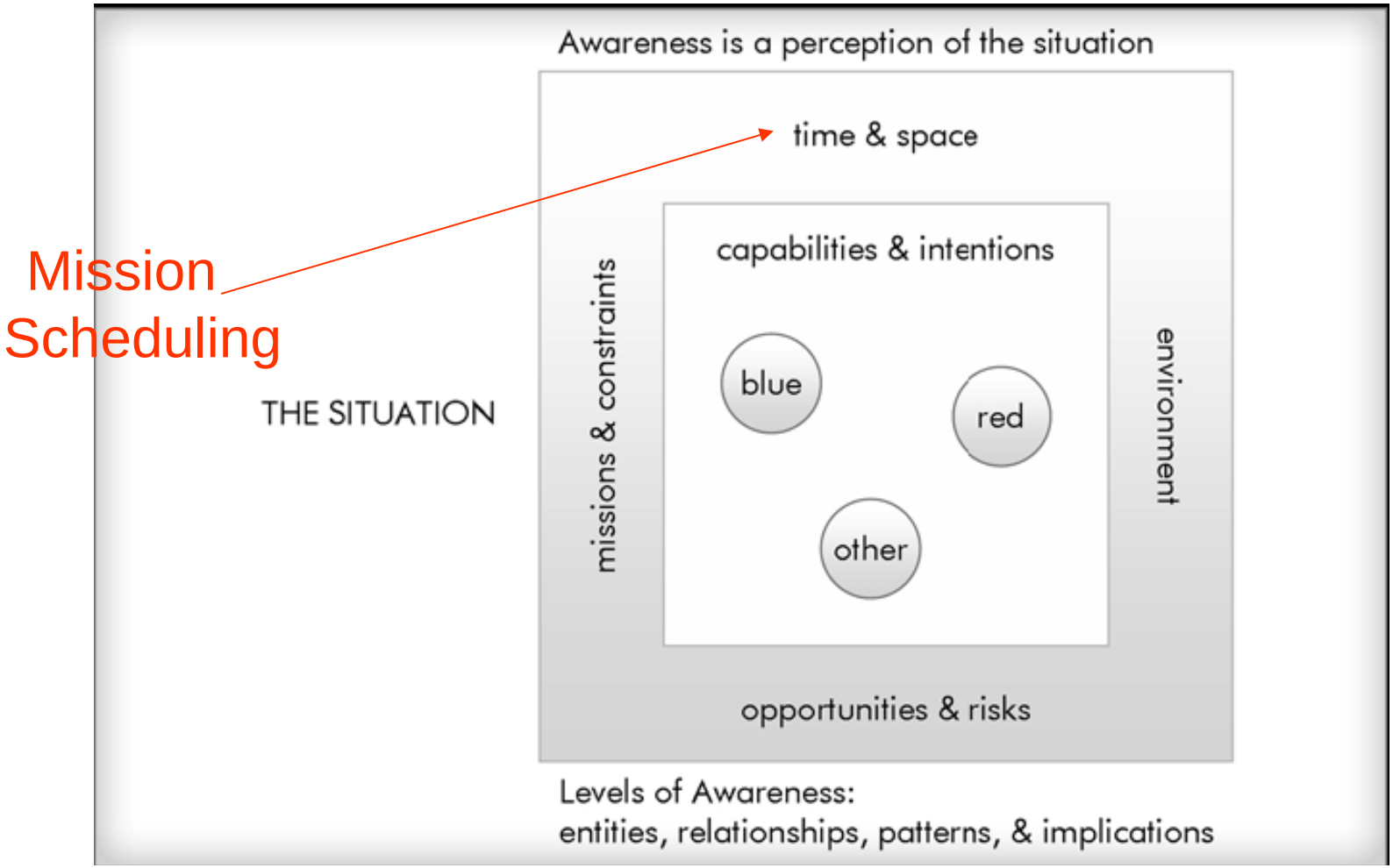

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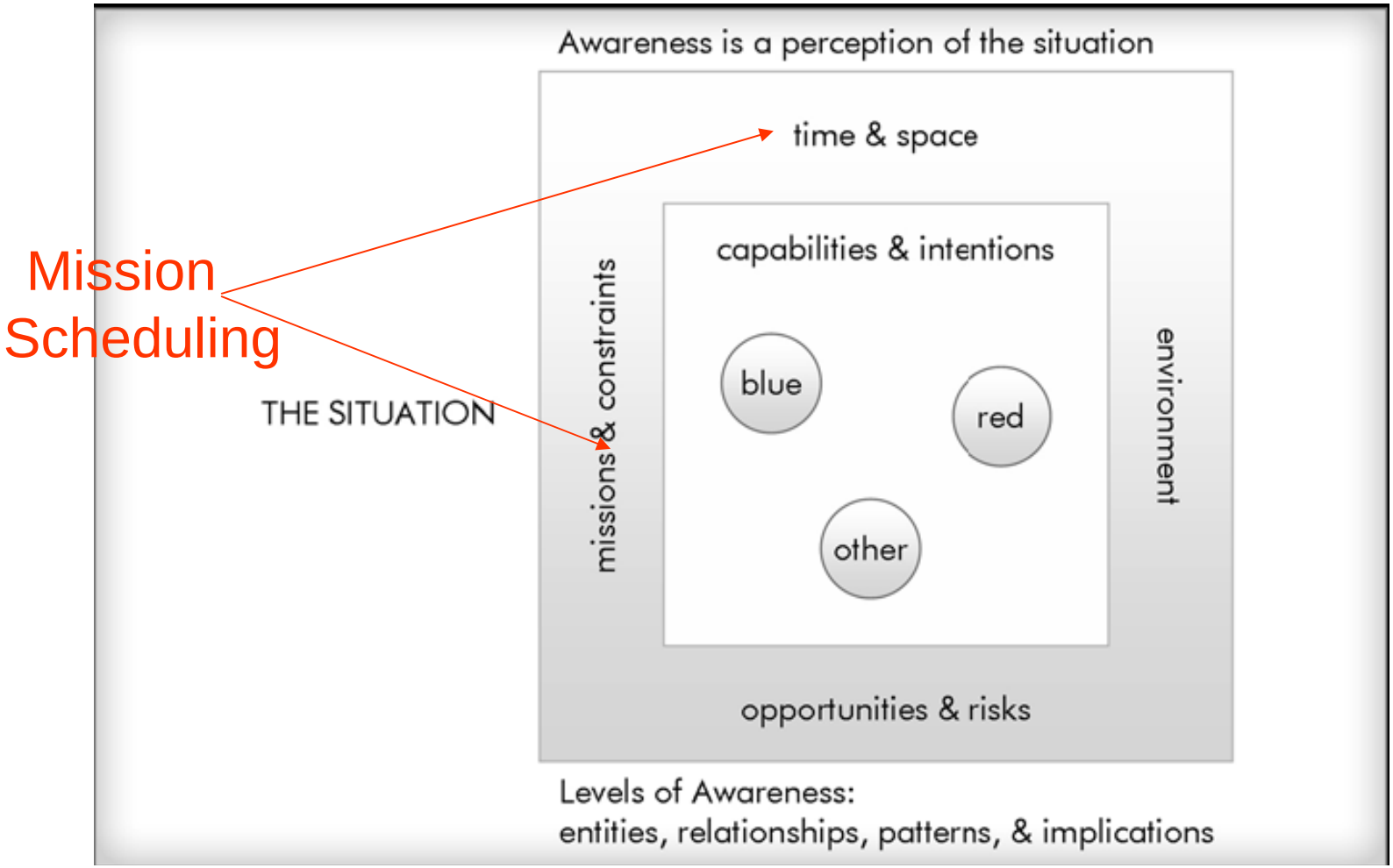

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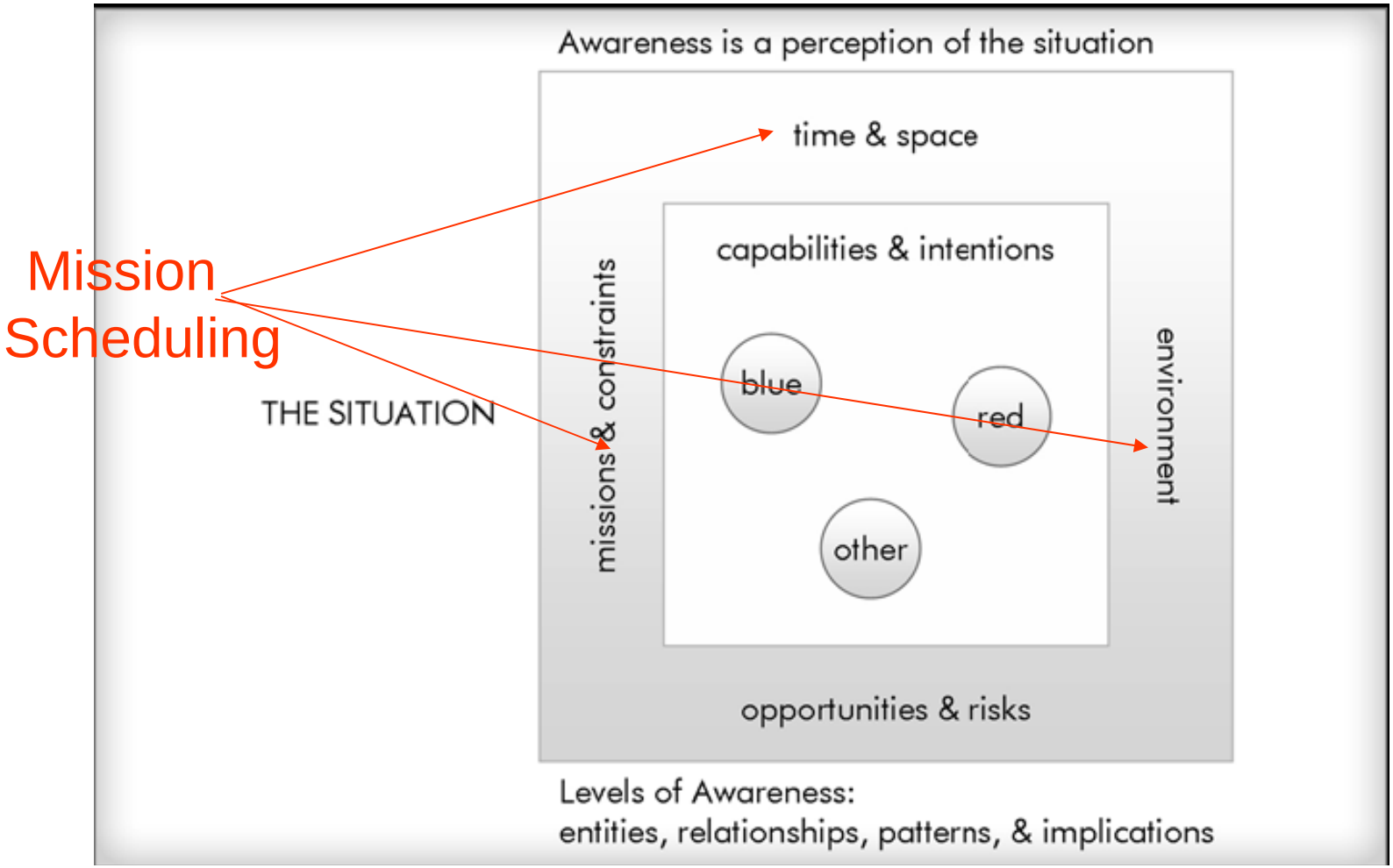

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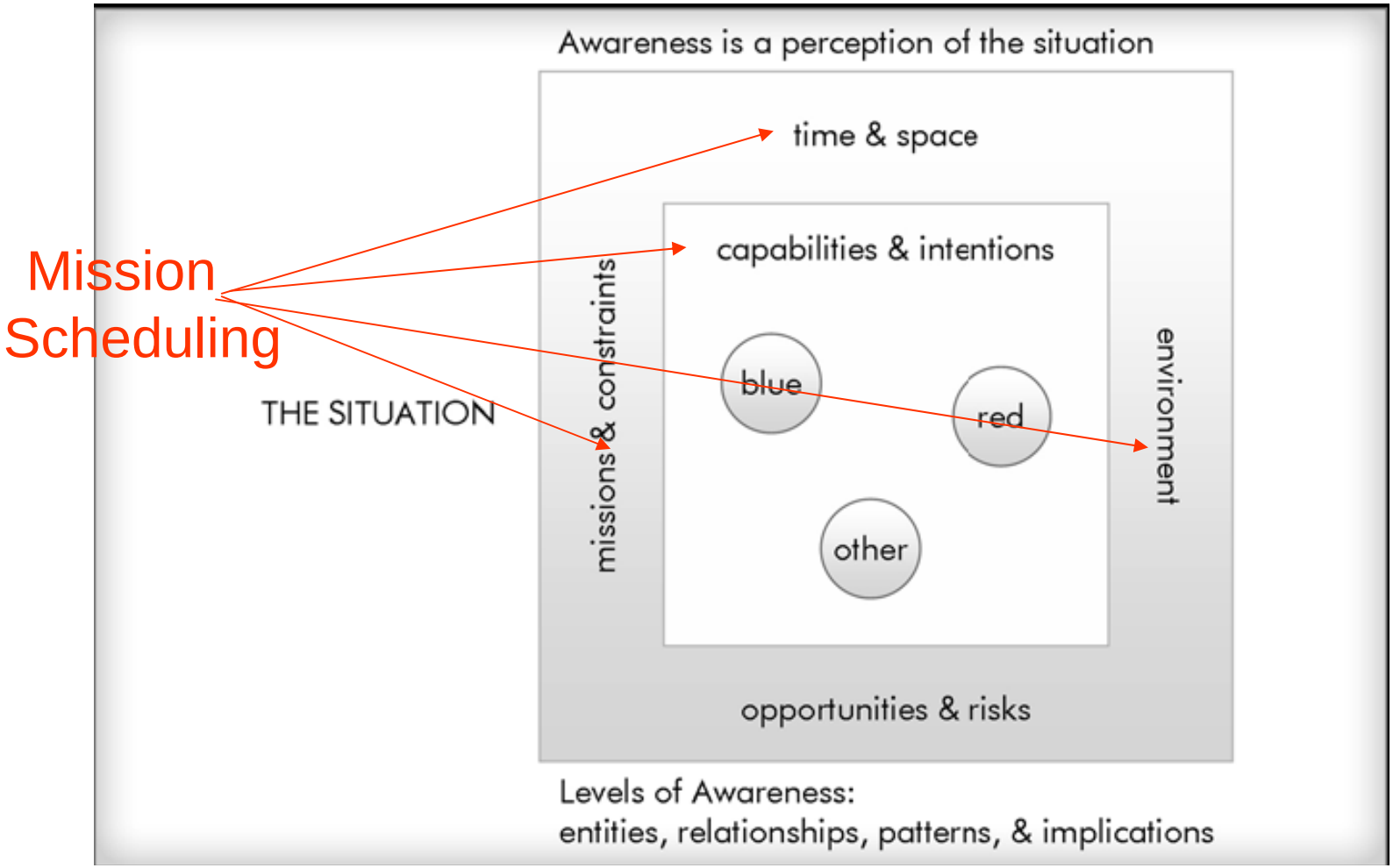

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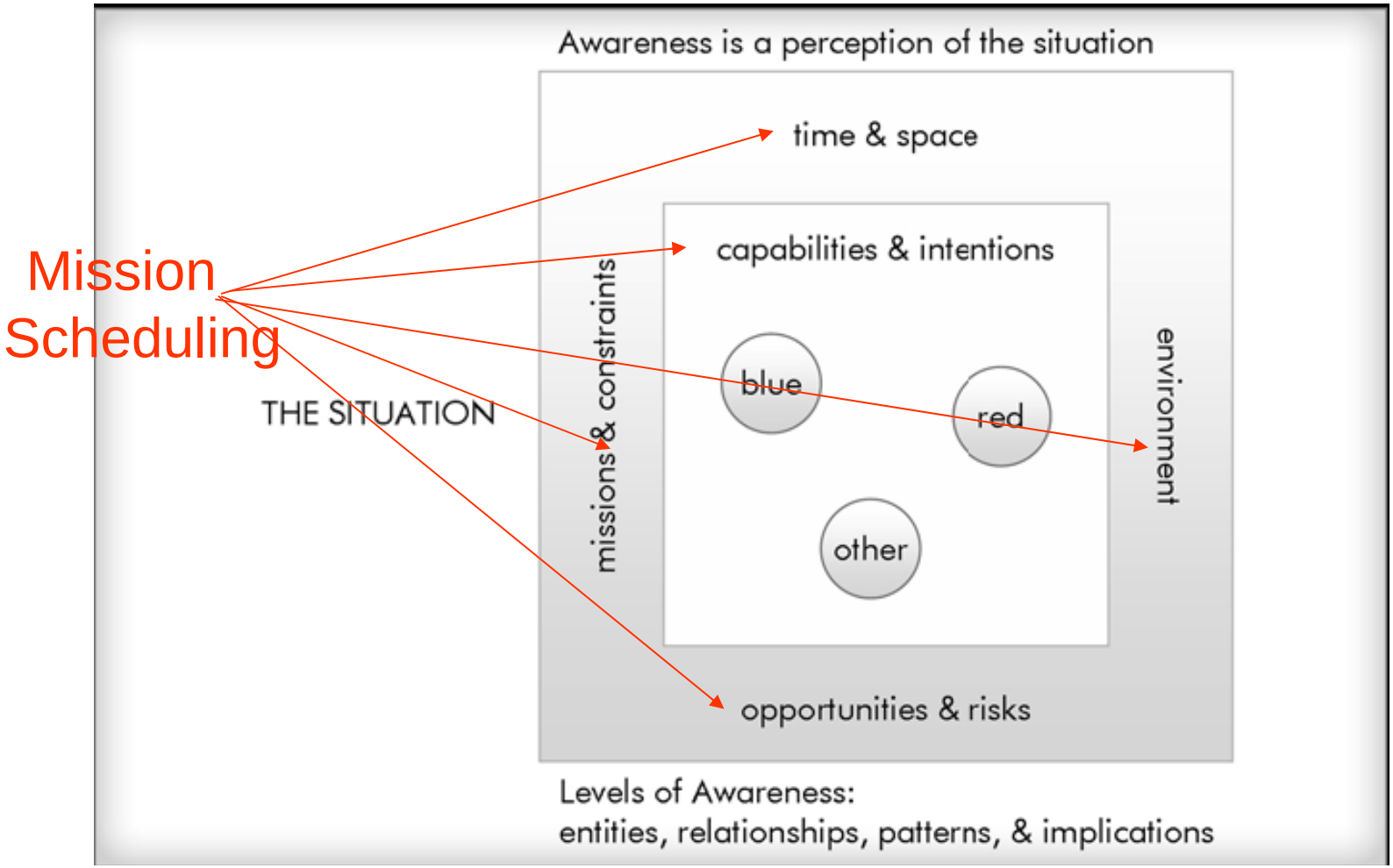
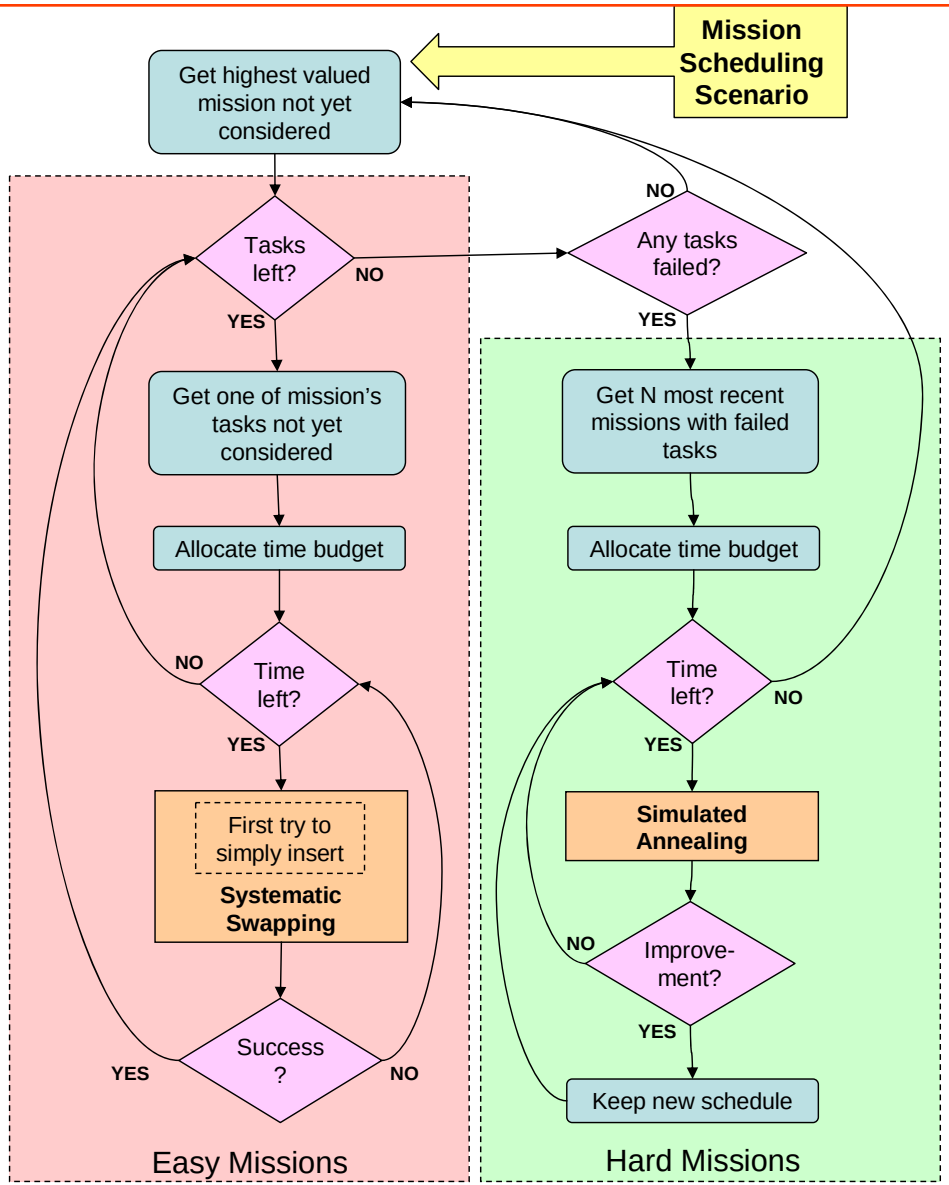


THE FUTURE OF COMMAND AND CONTROL: *UNDERSTANDING* COMMAND AND CONTROL, David S. Alberts and Richard E. Hayes, CCRP Publication Series, 2006, p. 153.

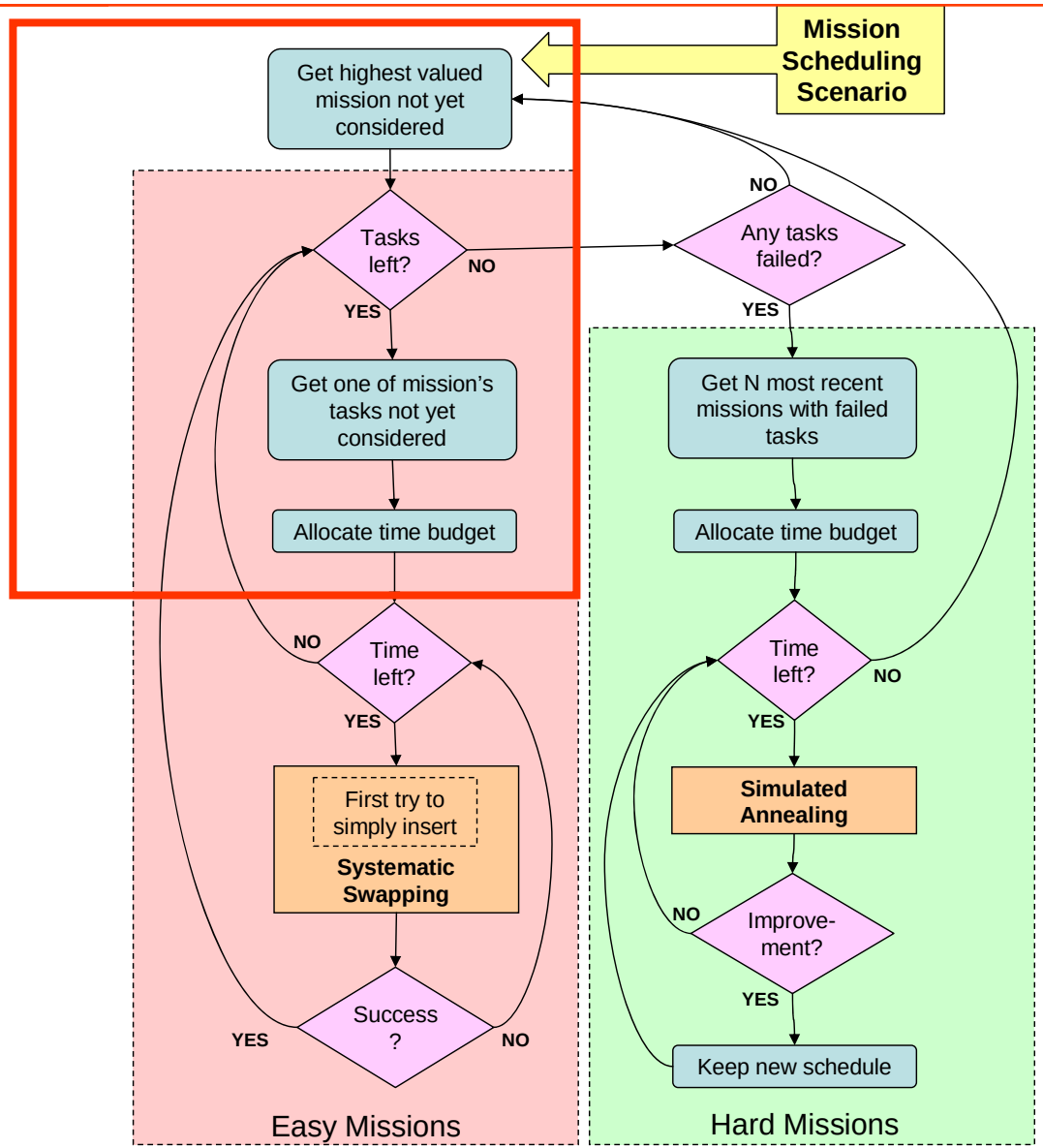
Optimizing the Mission Schedule for Mission Value

- Modern scheduling paradigms allow the creation of a schedule that is optimized for given parameter(s)
- The mission schedule can be optimized for Mission Value
  - Higher priority mission could be “bumped” by several lower priority missions when the overall mission value of the schedule is improved.
  - Need for care in determining the inputs to the Mission value computation when using optimization
    - Numerical separation between critical and non-critical tasks should be large enough to prevent unwanted aggregation of lower priority tasks outweighing a high priority task
    - Prioritization criteria may need to change over time to achieve desired results

Anatomy of a Cost-based Mission Scheduling Algorithm



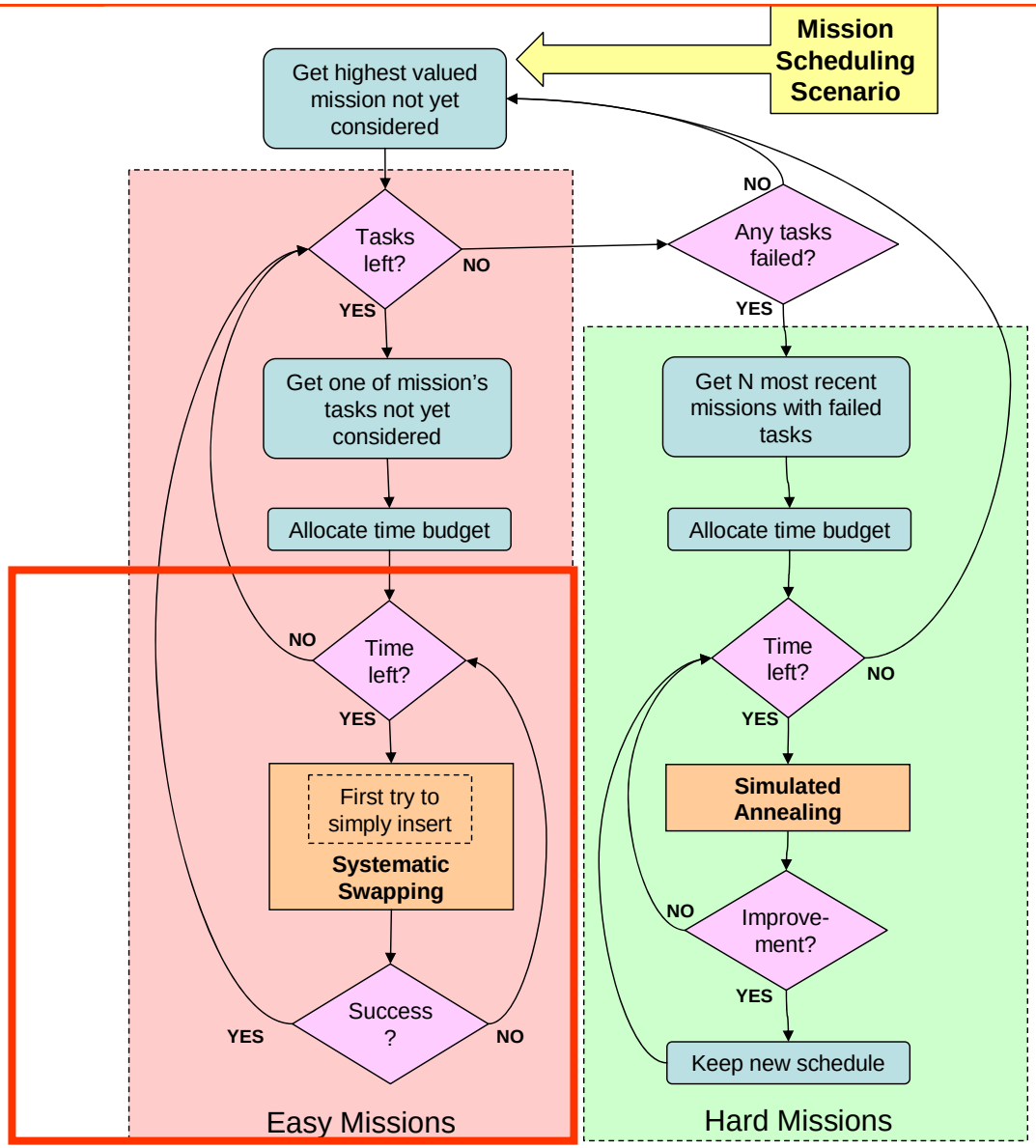
Anatomy of a Cost-based Mission Scheduling Algorithm - Greedy



Anatomy of a Cost-based Mission Scheduling Algorithm - Greedy

- Missions are added to the schedule using Mission Value
- Missions with highest mission value are added first
- Missions are added at their earliest actionable time
- As the schedule fills, it is harder to add new tasks

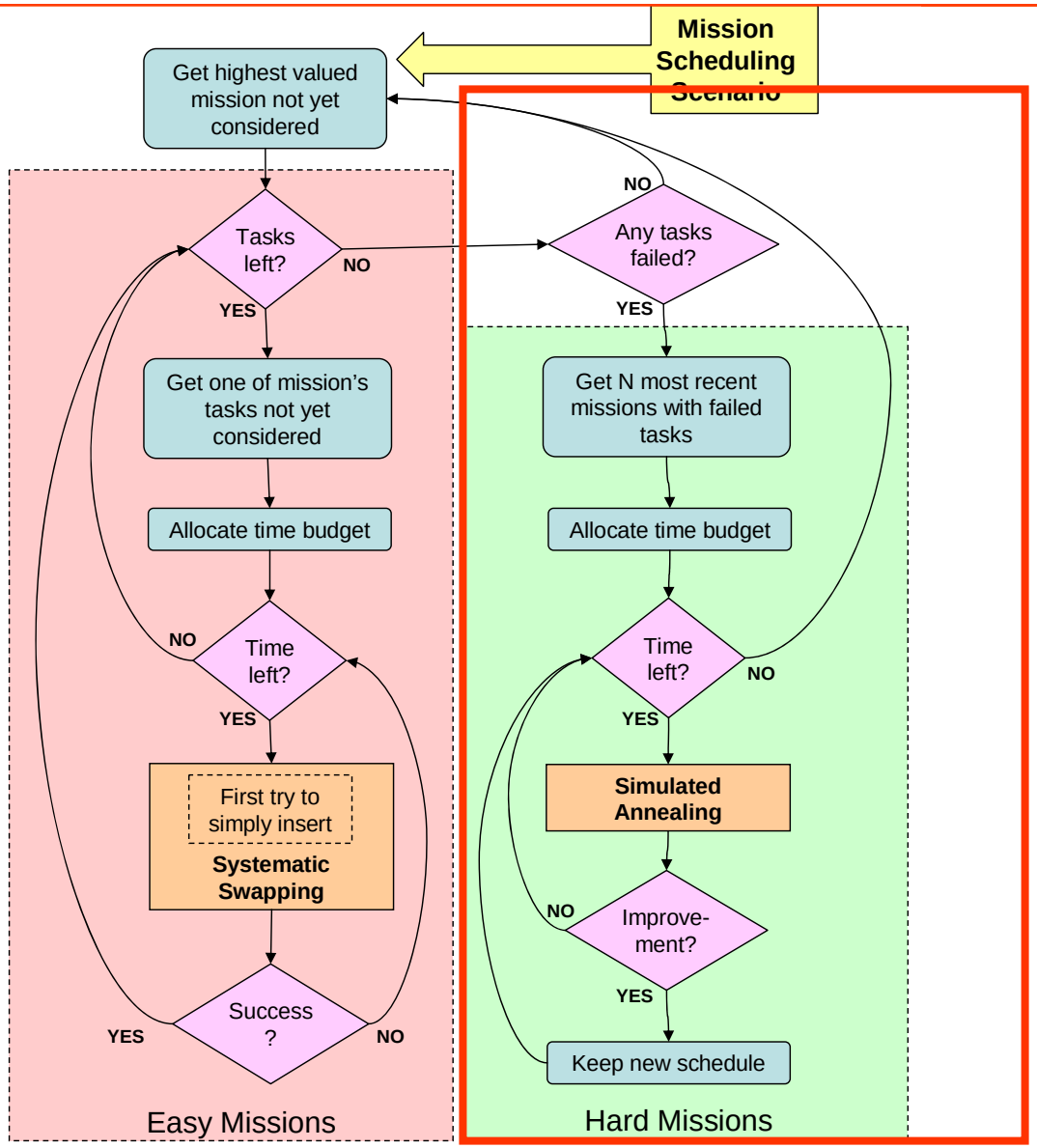
Anatomy of a Cost-based Mission Scheduling Algorithm – Systematic Swapping



Anatomy of a Cost-based Mission Scheduling Algorithm – Systematic Swapping

- A method of shifting and swapping tasks to free up adequate space to fit a given task
- Uses dynamic scheduling techniques
  - Uses the engagement window and duration of the task
  - Mission can be put on the schedule at any time within the engagement window
    - The start time + duration of the task must exist within the engagement window
- Shifts missions already on the mission schedule within their overall constraints to “fit in” the new mission
- Does not remove any previously scheduled missions

Anatomy of a Cost-based Mission Scheduling Algorithm – Simulated Annealing

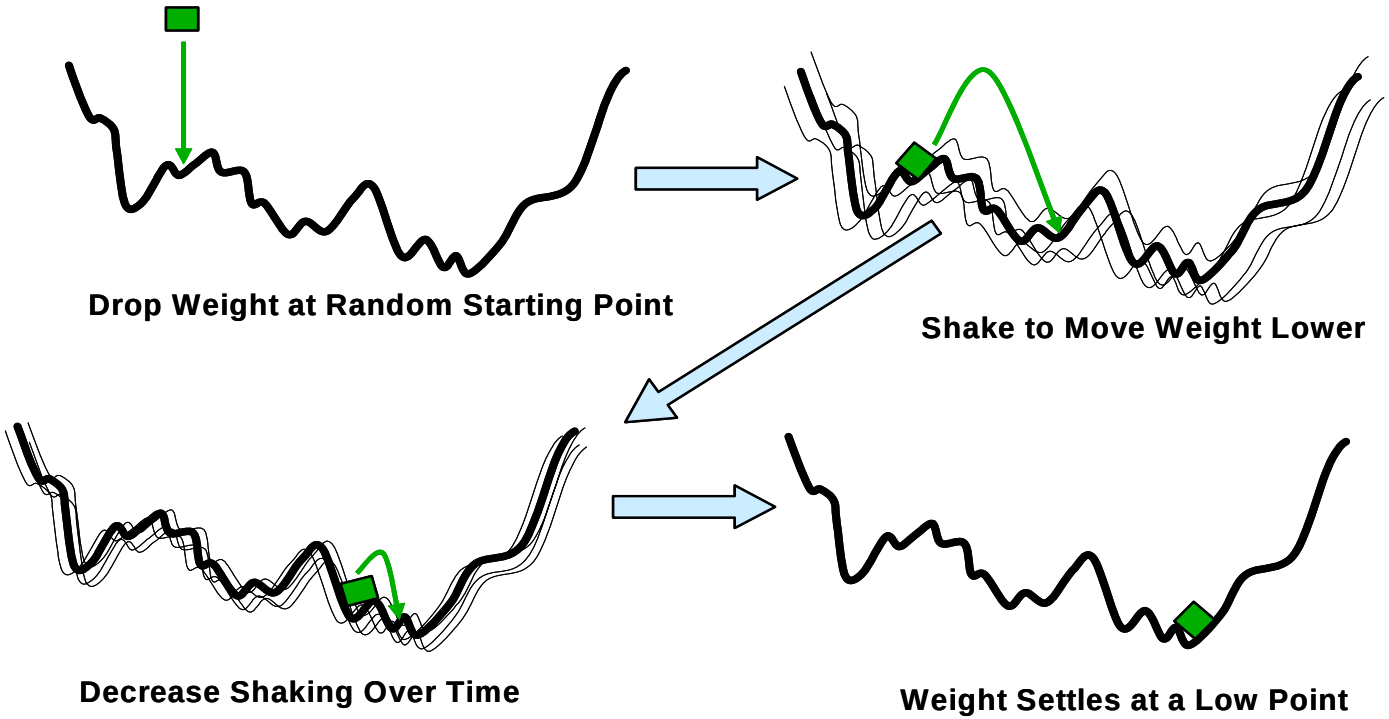


Anatomy of a Cost-based Mission Scheduling Algorithm – Simulated Annealing

- A local search method for optimization where a suboptimal solution is randomly perturbed in each iteration.
- The resulting new solution is then evaluated.
  - If it is better than the previous then it is accepted.
  - If it is worse than the previous solution then it is accepted with some probability, otherwise the solution reverts to the previous one.
- As the algorithm progresses, that probability decreases, such that by the end only improvements are accepted
- By accepting a worse solution the algorithm avoids local optima in its search for the global optimum

Use Simulated Annealing to Search for Better Scheduling

- Simulated annealing selects from randomized variants of current solution with a bias for improved performance/reduced resource violation
- Randomization prevents solution from settling into a local minimum
- Analogy - ind minimum of a function:



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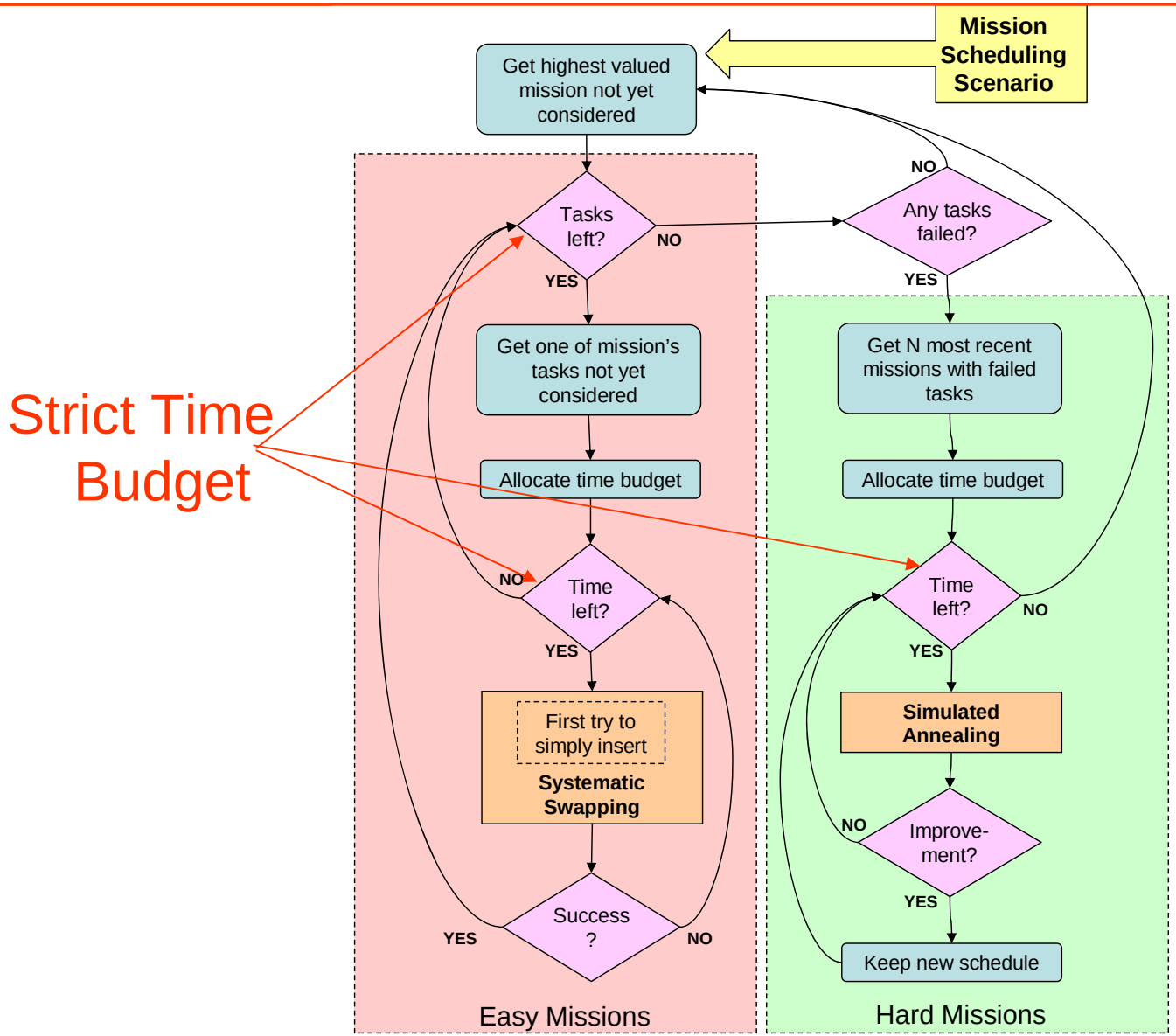

Next Steps

- Mission Value
  - Need to determine the revisit rate (if any) for computation of Mission Value
  - Need to ensure that when a new mission is added to the schedule, it is not given undue priority due to staleness of the Cost value for a mission already on the mission schedule
- Scheduling algorithms
  - Need to continue to evaluate potential algorithms for use in large scale scheduling problems
    - Scalability
    - Sophistication
    - Performance

Summary

- Net-centric Command and Control is complex
- Improved scheduling techniques such as dynamic scheduling aid in handling the large-scale scheduling problem
  - Three-tier scheduler
    - Greedy
    - Systematic Swapping
    - Simulated Annealing
  - Strict time budget
- Cost is a vital component to the scheduling because it introduces the concept of risk
- Mission Value provides an overall rank or priority of a mission **across** multiple mission areas