Graceful Degradation: A C2 Design Virtue for Our Times
ICCRTS Paper #3

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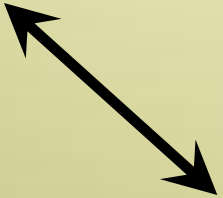
Key Terms for Graceful Degradation

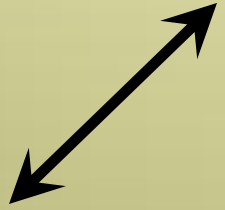
Graceful degradation occurs by virtue of the interaction of 3 aspects of system design

1. Hardware (Technology)
2. Software (Doctrine, procedures, instructions)
3. The human interface between hardware & software

Robustness
- **Resistance to change**
- **Resistance to uncertainty**



System Resilience → **Graceful Degradation** → **System Performance**



Redundancy
- **Active**
- **Passive**
- **Type**
- **Action**

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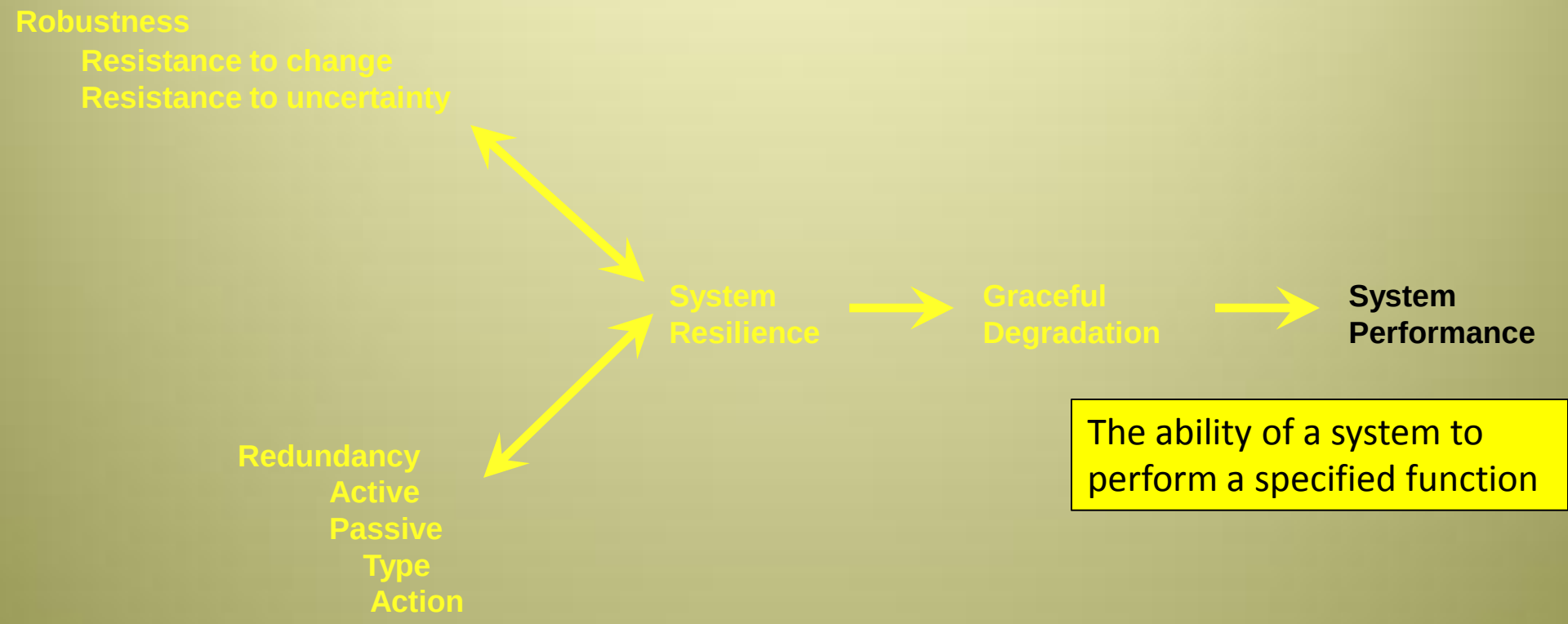

The ability of a system to perform a specified function

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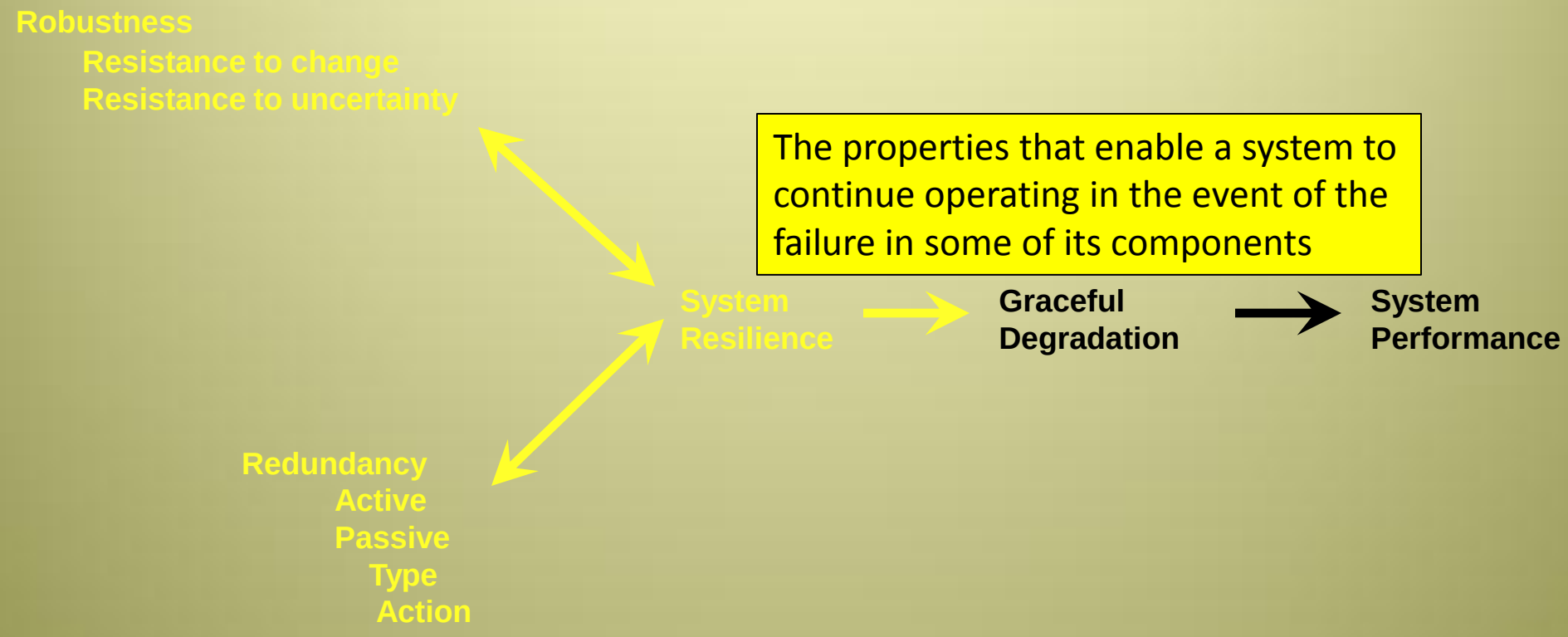

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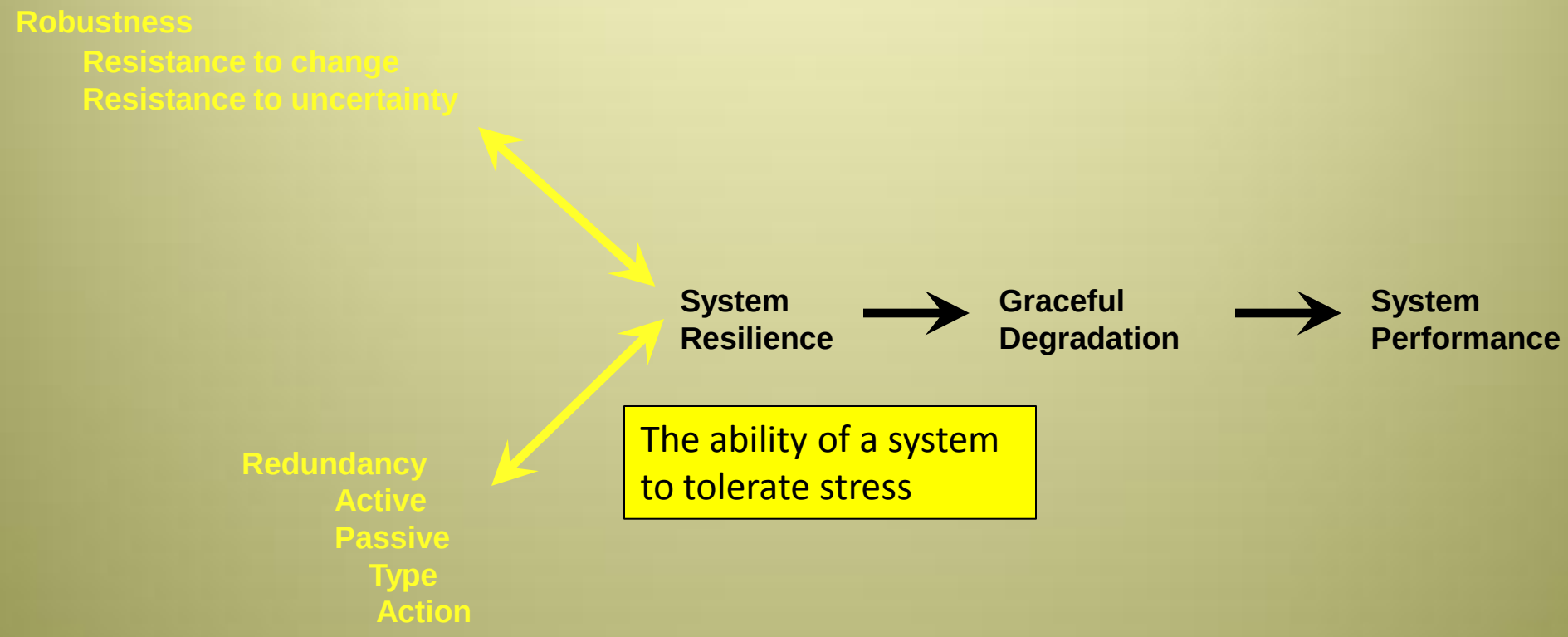


Key Terms for Graceful Degradation

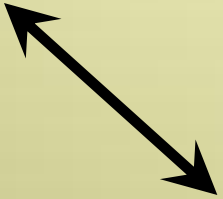
The *strength* of a system:

- Ability to resist changes from both in/out
- Ability to resist the uncertainties associated with system processes

Robustness

Resistance to change

Resistance to uncertainty



System Resilience

Graceful Degradation

System Performance

Redundancy

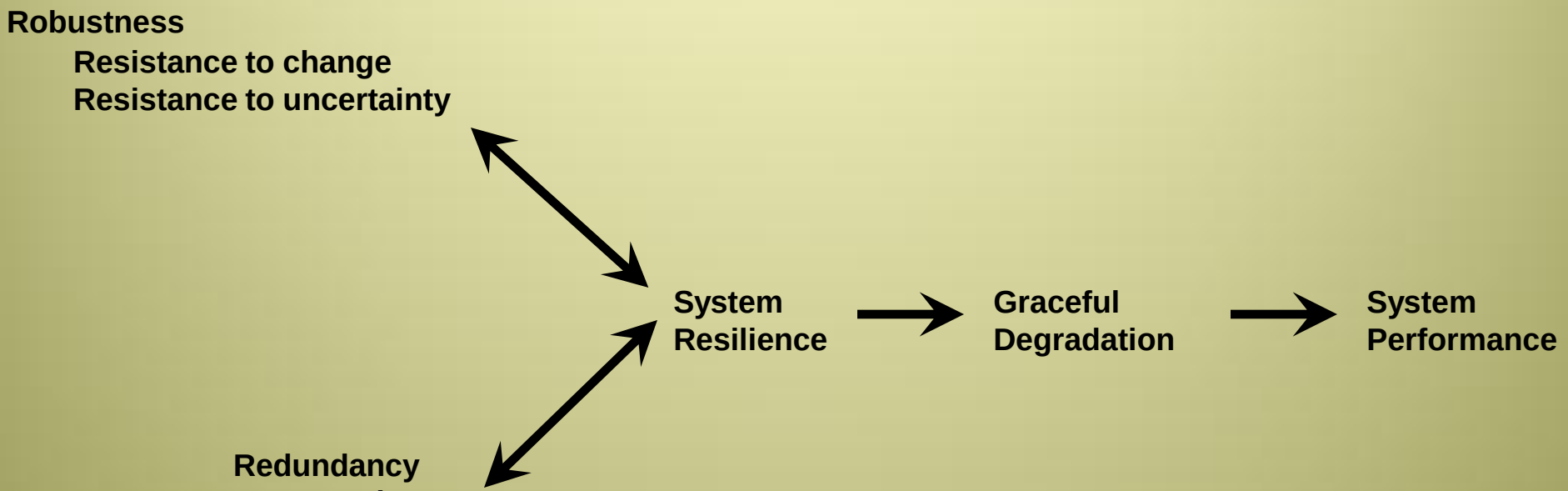
Active

Passive

Type

Action

Key Terms for Graceful Degradation



A *multiplicity* of probable system operational capabilities

- Active: Alternate system components can accomplish the same thing
- Passive: A non-operational “back-up” component is available

Domain Review of Resilience

Degree of Complexity

	Materials Engineering	Systems Engineering	Social-ecological System Mgt	Critical Infrastructure Mgt
Focus	**Discrete part of the system**	**Groups of interacting parts**	**Adaptive Capacity**	**System Protection**
Purpose	**Design the system part to endure stress/minimize change**		**Design the system as a whole to tolerate stress and adapt**	**Design the system to withstand both unintentional and intentional damage**
Insights	**Assumes there is one "normal" state to which a system returns after a disturbance**		• **The "parts" of these systems are inherently adaptable** • **Explicitly recognizes humans as part of the system**	**Tightly-coupled systems with circular, reciprocal dependencies can lead to cascading or escalating failures in other systems**

Six Case Studies on Graceful Degradation

- **Hardware**
  - **Successful: USS San Francisco, Guadalcanal – 1942**
  - **Unsuccessful: Hurricane Katrina – 2005**
- **Software**
  - **Successful: Battle of Wanat – 2008**
  - **Unsuccessful: Operation *Fall Gelb* – 1940**
- **Human Interface**
  - **Successful: Task Group 77.3, Battle off Samar – 1944**
  - **Unsuccessful: 1st Army, Huertgen Forest Campaign – 1944**

Observations and Recommendations

- **Resilience requires trade-offs**
- **Resilience requires disturbances**
- **Resilience requires an acceptance of unpredictability**
- **Increasing resilience is dependent upon selecting actions that are informed by the existing system state**
- **Resilience requires a culture that:**
  - **Allows a variety of leadership styles**
  - **Fosters a high degree of trust**
  - **Uses decisions that retain all options open**
  - **Provides the capacity and capability to self-organize & reorganize**

CCJO and Graceful Degradation

- **Educate commanders and staffs to match their command philosophy to the particular requirements of each mission**
- **Regularly train the force to operate in "worst case" degraded environments**
- **Make a common set of C2 applications available as cloud services**
- **Build greater resilience into technical architectures**
- **Develop capabilities and tradecraft that provide broader intelligence to decision makers**
- **Improve the capabilities that fuse, analyze, & exploit large data sets**