24th ANNUAL NATIONAL TEST & EVALUATION CONFERENCE

Test and Evaluation of Autonomous Systems & The Role of the T&E Community in the Requirements Process

STM AŞ

APPLICATION OF EVOLUTIONARY STRATEGIES FOR ACQUISITION OF AUTONOMOUS SYSTEMS

Dr. Ebru SARIGÖL Nuri M.ÇERÇİOĞLU Dr. Anıl KAREL

24th ANNUAL NATIONAL TEST & EVALUATION CONFERENCE

Test and Evaluation of Autonomous Systems & The Role of the T&E Community in the Requirements Process

Presented By
Dr. Ebru SARIGÖL

Palm Springs, CA
26 February 2008

STM AŞ

APPLICATION OF EVOLUTIONARY STRATEGIES FOR ACQUISITION OF AUTONOMOUS SYSTEMS

Outline

- Introduction
- New Acquisition Environment: Evolutionary Acquisition
  - Development and Lifecycle models
- Testing in Evolutionary Acquisition Environment
- An Approach to Procurement of an Autonomous System
- Test Design with Staged Development
- Conclusion

Introduction

- It is very often that a systems engineer faces to participate in procurement studies or make procurement decisions which affect significantly the success of a project.
- Procurement decisions may
  - be complex
  - involve inputs from many organizations
  - include technical and non-technical constraints.

- MAIN AIM: to fulfil/achieve/realize the procurement of users /the demanding authority in a reasonable time interval.
- Many parameters
  - budget
  - procurement time
  - user and/or system needs
  - properties of the system to be procured
  - priorities of the sub-systems present in the system (indispensable, should be, preferable)
  - technological maturity/perfection
  - technologies to be developed
  - possibility of retreofil of the of the system
  - determination of the tests to be done
  - timing of the tests.

New Acquisition Environment

- Evolutionary acquisition (EA) is a process for defense system development in which a system is developed in stages as a part of a single acquisition program.
- The different stages can be additional hardware and software capabilities or performance gains due to advances in technological maturity and reliability growth.

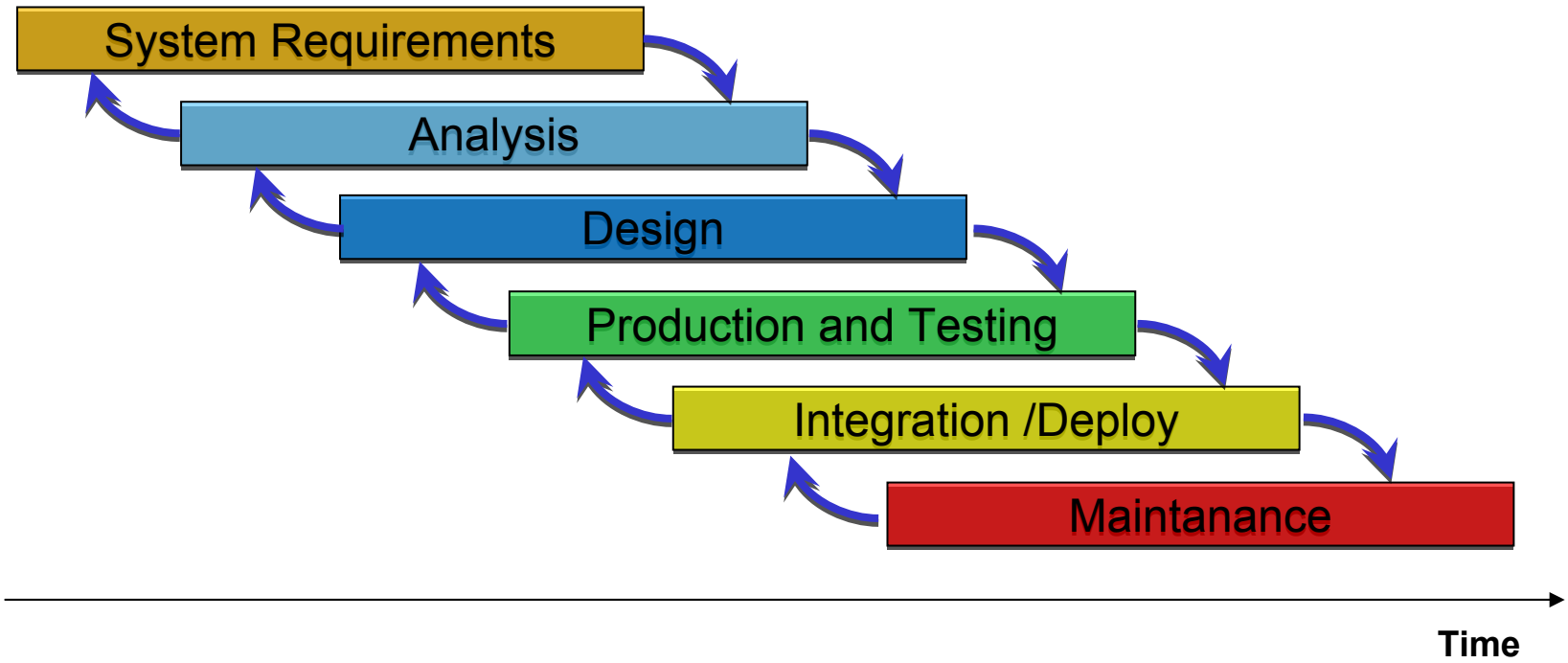
New Acquisition Environment

- In an evolutionary approach, the ultimate capability delivered to the user is provided in increasing increments.
- Evolutionary acquisition strategies
  - (1) define, develop, produce and deploy an initial, military useful capability (Increment 1) based on proven technology, demonstrated manufacturing capabilities and time-phased capabilities needs;
  - (2) plan for subsequent development, production and deployment of increments beyond the initial capability over time (Increments 2 and beyond).

- There are various development and Lifecycle models to support systems engineering within an evolutionary acquisition strategy.
  - waterfall
  - iterative
  - spiral development
  - Vee

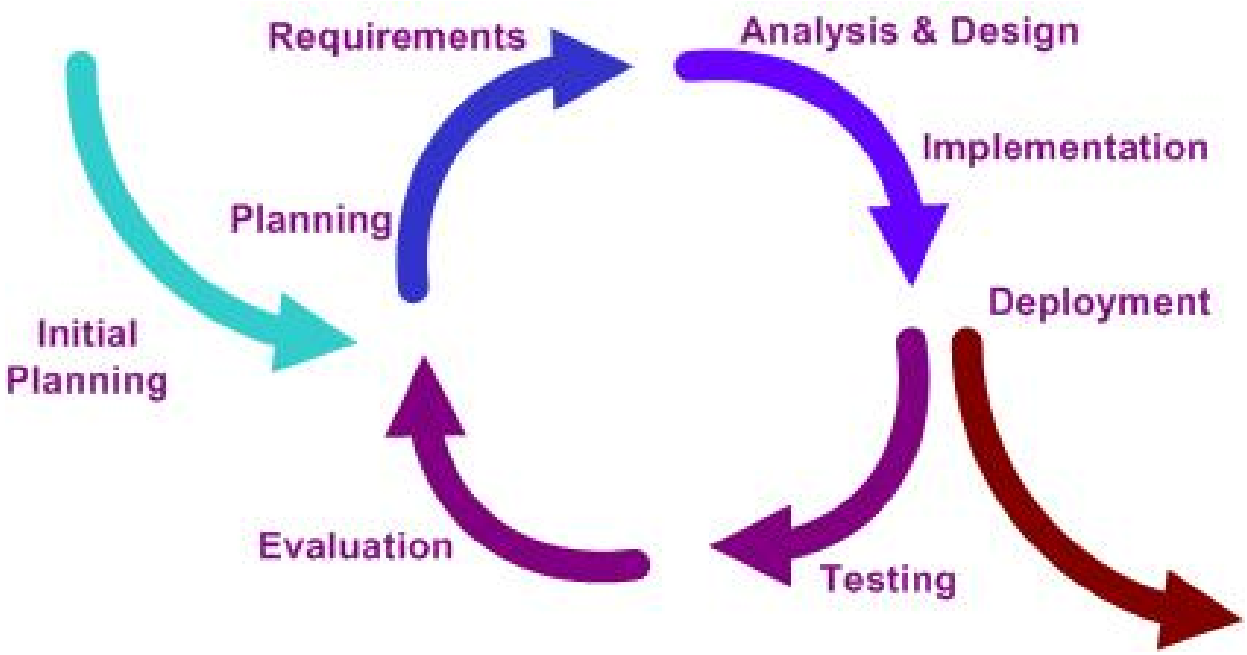
Waterfall Model

- It is a sequential software development model (a process for the creation of software) in which development is seen as flowing steadily downwards (like a waterfall) through the phases of project



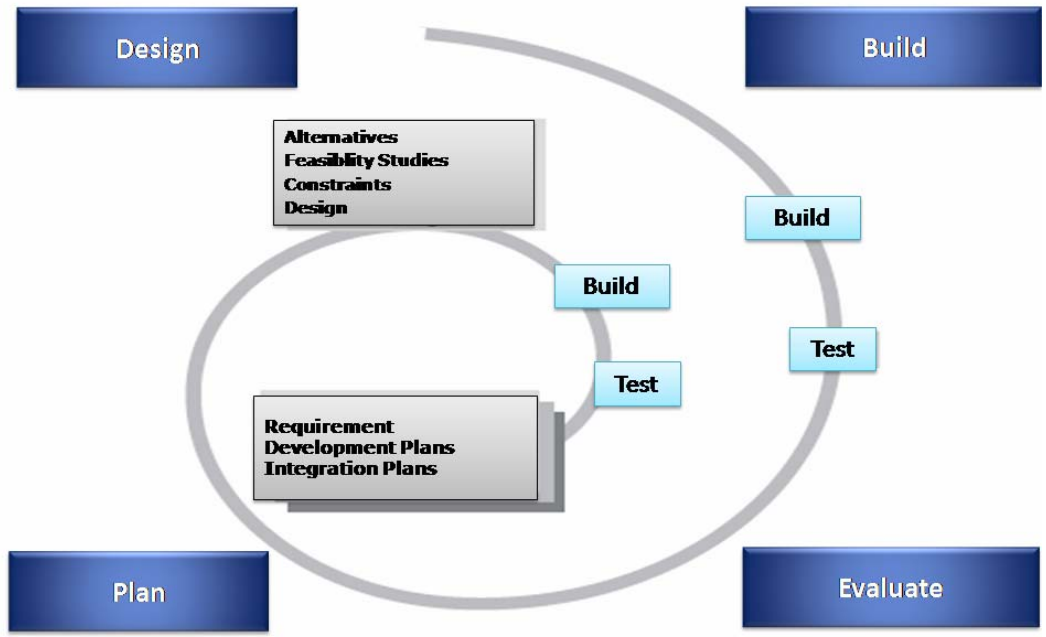
Iterative Model

- Iterative development is a rework scheduling strategy in which time is set aside to revise and improve parts of the system.
- It does not presuppose incremental development, but works very well with it.



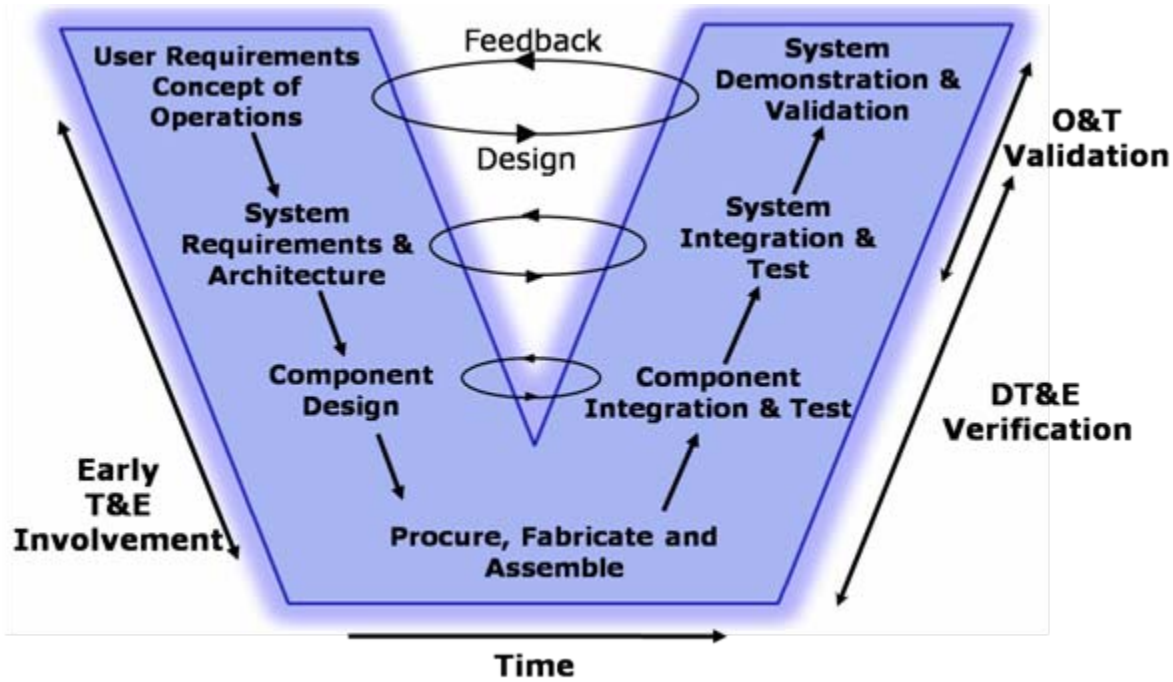
Spiral Development Model

- a systems development method used in information technology.
- combines the features of the prototyping model and the waterfall model.
- favored for large, expensive, and complicated models



Vee-Model

- a systems development model designed to simplify the understanding of the complexity associated with developing systems.
- used to define a uniform procedure for product of project development.

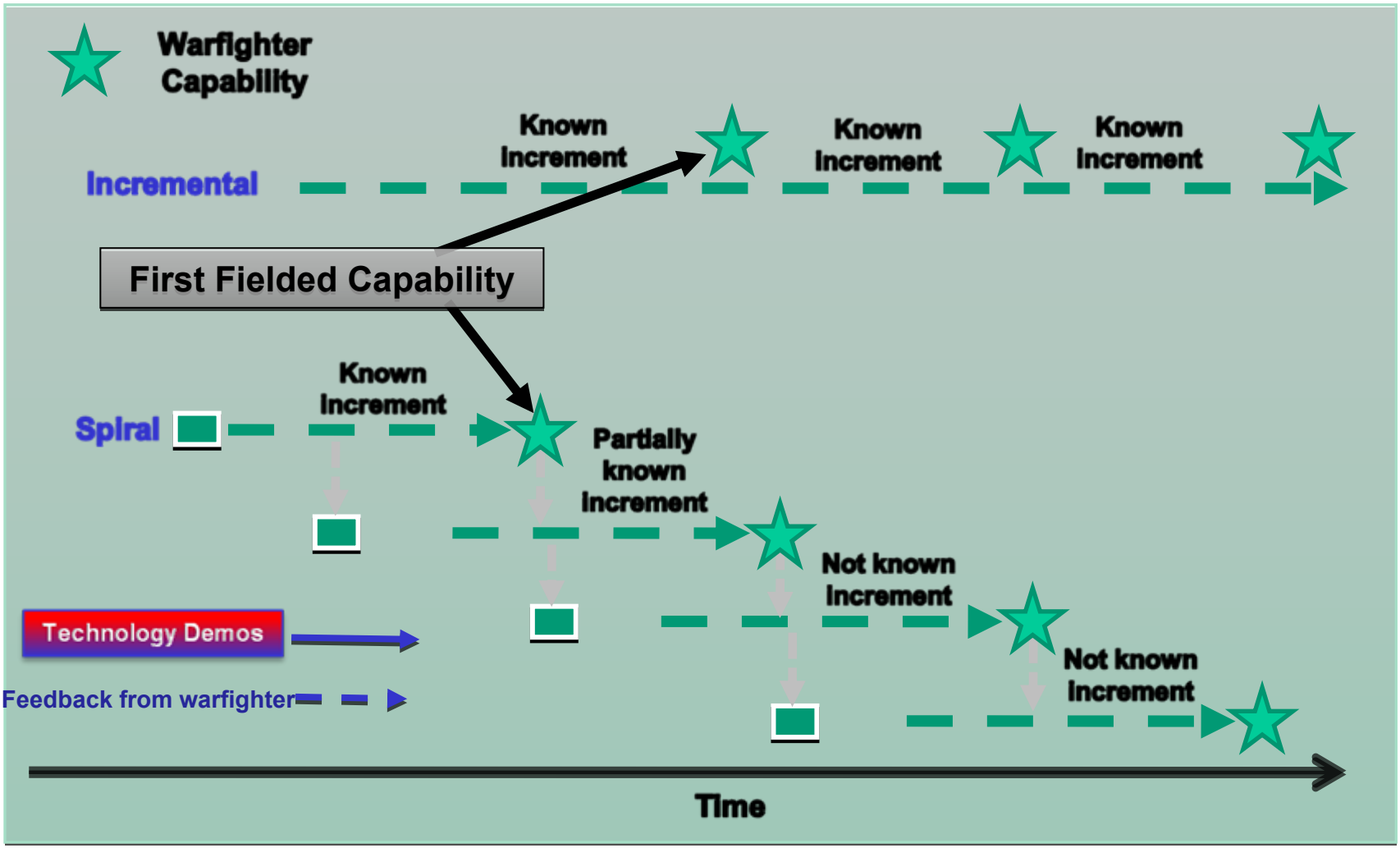


New Acquisition Environment

- All models provide an orderly approach to implementing and integrating the systems engineering processes during each acquisition phase.
- Waterfall model is not practical to imply for all systems
- In iterative model, the end-state requirement should be known but this model allows earlier delivery of initial planned system
- In spiral and incremental development, capability is developed and fielded in increments with each successive increment building upon earlier increments to achieve an overall capability.
- The spiral and Vee models rely heavily on prototyping, both physical and virtual, to get user feedback.

STM

Comparison of the incremental and spiral evolutionary processes



Evolutionary Acquistion is a strategy not a model

- Can be adjusted for any project
- General description of desired full system functional capability
- Concise statement of full system operational concepts
- Flexible overall architecture allowing incremental design
  - One method is the use of Open Systems Architecture
- Plan to incrementally achieve desired total capability
- Early definition, funding, development, testing, supporting and operational evaluation of initial increment of operational capability
- Continual dialogue and feedback among users, developers, supporters and testers

New Acquisition Environment

- **Evolutionary** acquisition
  - increased the importance of traceability in program management.
    - If a defense system has multiple increments, systems engineering can trace the evolution of the system.
    - It can provide discipline to and documentation of the repeated trade-off analyses and decisions associated with the program.
  - Due to the nature of **evolutionary** acquisition, design, development, deployment, and sustainment can each be occurring simultaneously for different system increments.

Testing in Evolutionary Acquisition Environment

- Test and evaluation may be at the end of the development phase which was the path in earlier and simple procurement models
- ⇨ leads to a deficiency in the technological maturity level as well as an increase in acquisition time of the required system.
- Instead integrated test and evaluation should be preferred for the optimization of procurement time and necessary technological maturity level

Testing in Evolutionary Acquisition Environment

- In the evolutionary acquisition context
  - experimentation in early stages
    - to identify system flaws
    - understand the limitations of system design.
  - experimentation in later stages
    - problems identified in the field and/or unresolved from earlier testing
    - evaluating the most recent modifications to the system, and assessing the maturity of a new component or subsystem design.
      - ☑ This experimentation can be at the component level, at the subsystem level, or at the system level, with varying degrees of operational realism, depending on the goals.

Testing in Evolutionary Acquisition Environment

- Operational testing and evaluation supports a decision to pass or to fail a defense system before it goes to procurement.
- In EA, entire spectrum of testing activities should be viewed as a continuous process of gathering, analyzing, and combining information in order to make effective decisions.
- The primary goal of test programs should be to experiment, learn about the strengths and weaknesses of newly added capabilities or (sub)systems, and use the results to improve overall system performance.
- Furthermore, data from previous stages of development, including field data, should be used in design, development, and testing at future stages.

Testing in Evolutionary Acquisition Environment

- Operational testing (testing for verification) of systems still has an important role to play in the evolutionary environment, although it may not be realistic to carry out operational testing comprehensively at each stage of the development process.
- Testing early in the development stage should emphasize the detection of design inadequacies and failure modes.
- In evolutionary acquisition, it will be practical to conduct full-scale operational tests only at stages with major upgrades or substantive new capabilities.
- In the evolutionary acquisition environment, effective system development and optimization will require a high degree of coordination and communication among system developers, government testers, and system users.

Testing in Evolutionary Acquisition Environment

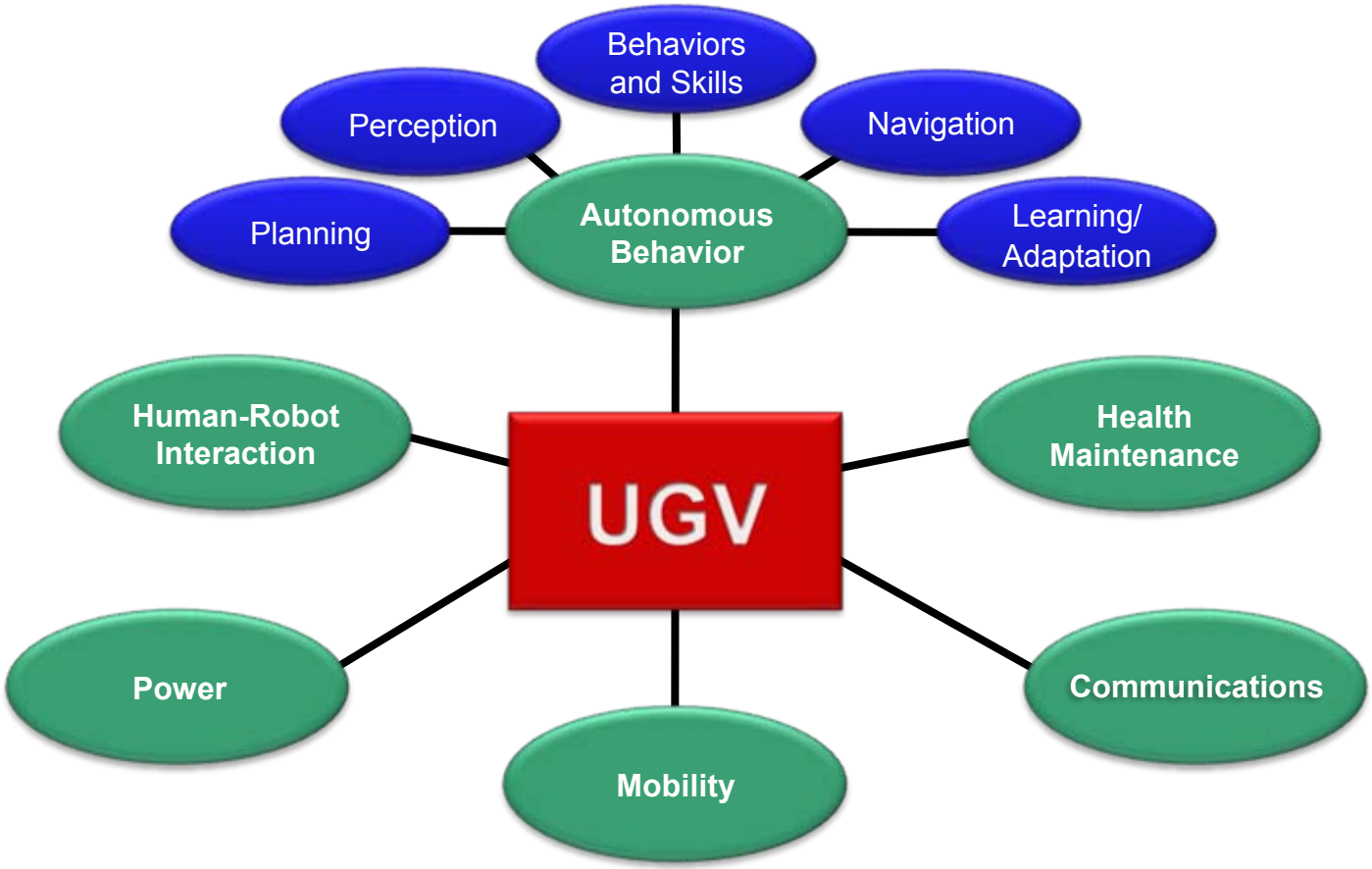
- The traditional single-stage acquisition environment can encourage the adoption of risky, immature technology into an existing system, since it may take a decade or more before a new technology can be incorporated.
- Regardless of the introduction of evolutionary acquisition, the increasing complexity of defense systems implies that a single all-encompassing, large-scale operational test, as currently practiced, will not be feasible in many cases.

Testing in Evolutionary Acquisition Environment

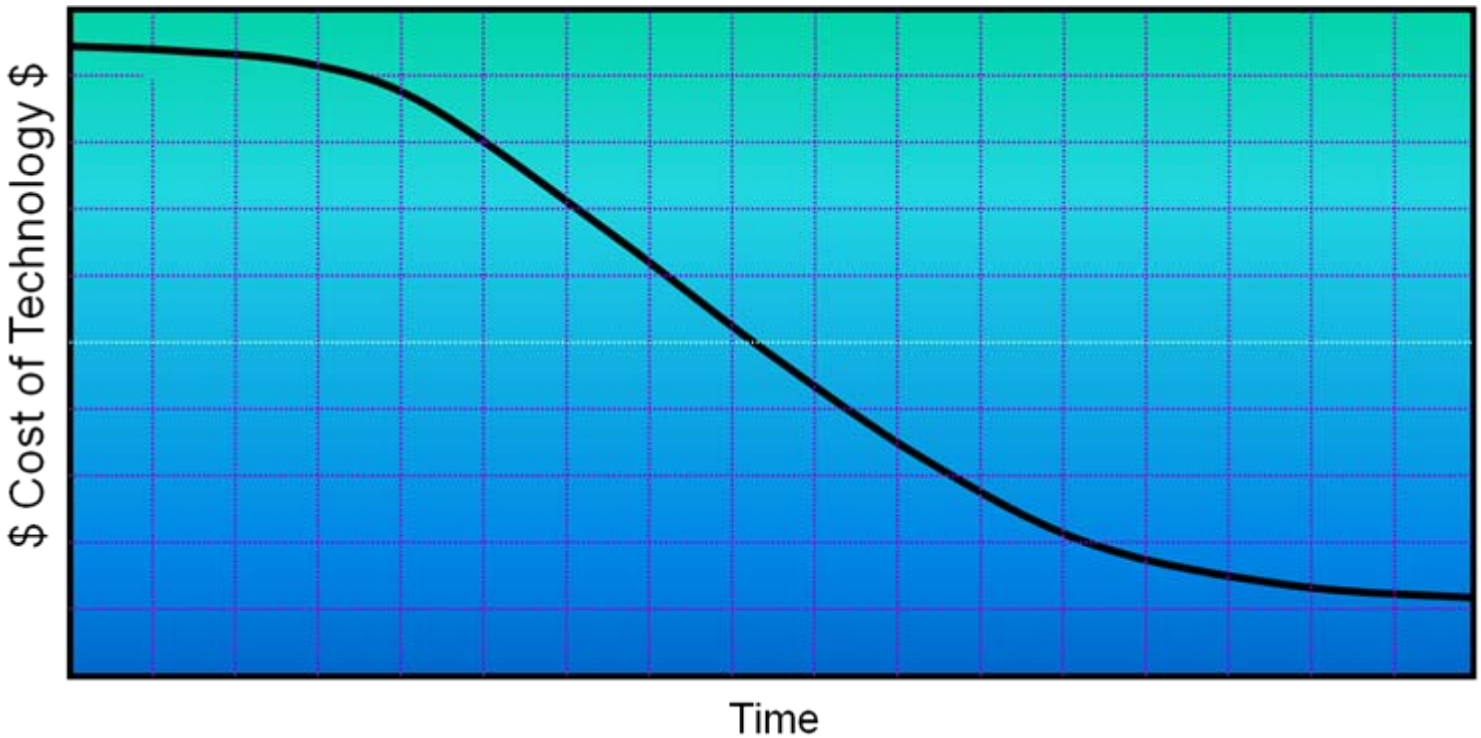
- Evolutionary acquisition is being folded into an acquisition environment that already has a counterproductive incentive system. The flexibilities inherent in the evolutionary acquisition process present even greater opportunities for these counterproductive incentives to be expressed.
- Testing early in the development stage should emphasize the detection of design inadequacies and failure modes. This will require testing in more extreme conditions than those typically required by either developmental or operational testing, such as highly accelerated stress environments.

An Approach to Procurement of Autonomous System

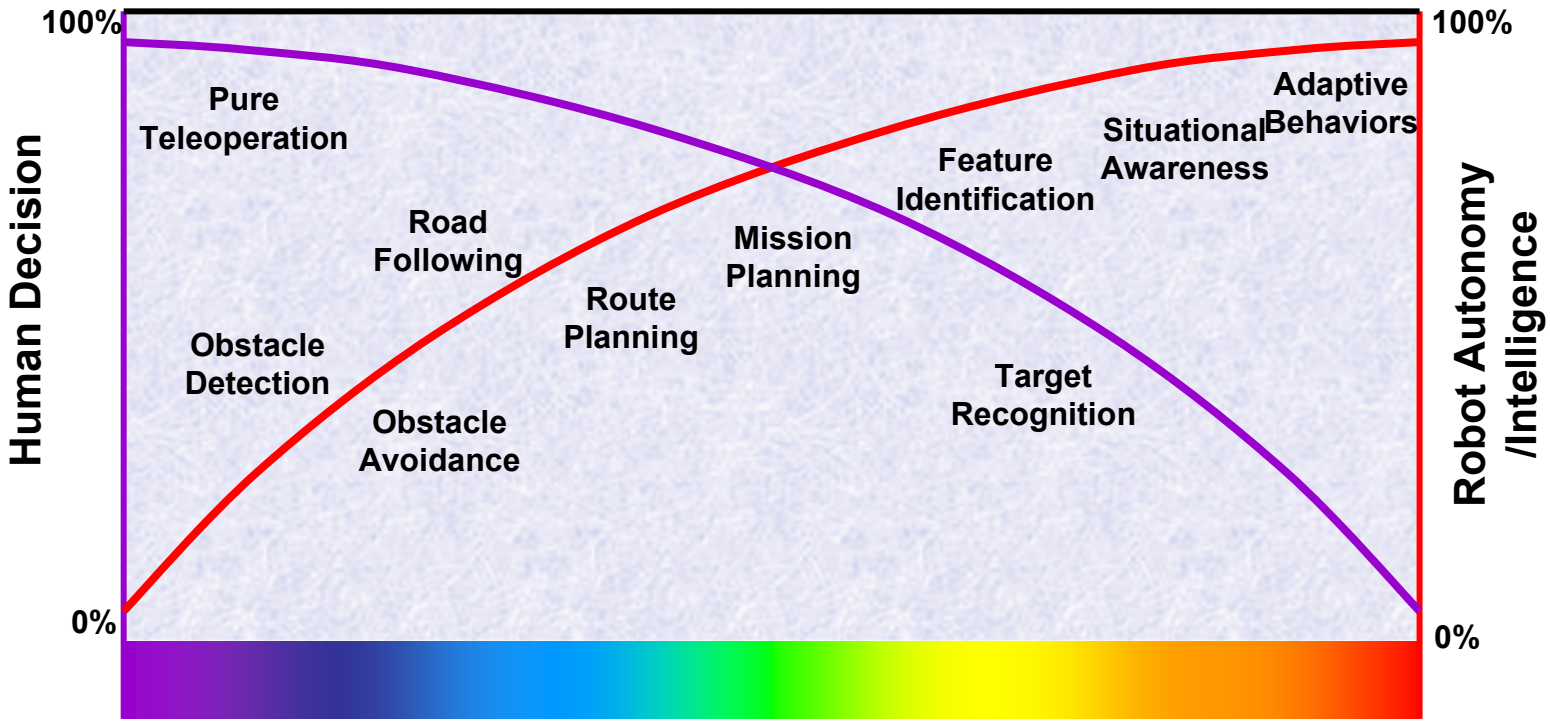
- Autonomous Behavior Technologies
- Supporting Technologies



- Field systems with today's reliable & affordable technology
- Insert new technologies as they become reliable & affordable



An Approach to Procurement of an Autonomous System



- The development process will be best served by systematic and extensive testing and refinement under severe operating conditions.
- Focusing on a few specific applications for the experimental prototypes, some of which may be simulated, is essential to maturing the needed technologies and resolving the significant issues of system integration.

- The user and developer communities must work together to provide direction for the technology integration to implement vehicle experiments.
- These directions should feed into the spiral development process from experimental prototypes to requirements-based systems following the established development process.
  - i.e. application parameters must be formulated to address the integration of the mission-package technologies, mobility technologies, and communications technologies that are necessary for each experimental prototype.

A SIMPLE EXAMPLE WITH TWO FACTORS

$$Y = \beta_{00} + \beta_{10} x_1 + \beta_{20} x_2 + \varepsilon$$

Stage (k-1) ⇨ **SUNNY** vs **RAINY**

For details see “Testing of Defense Systems in an Evolutionary Acquisition Environment”

Test Design with Staged Development

Stage (k) ⇨ **NIGHT VISION CAPABILITY**

$$Y = \beta_{00} + \beta_{10} x_1 + \beta_{20} x_2 + \beta_{12} x_1 x_2 + \varepsilon$$

Test scenarios with more than two levels and quadratic terms:

$$Y = \beta_{00} + \beta_{10} x_1 + \beta_{11} x_1^2 + \beta_{20} x_2 + \beta_{21} x_2^2 + \beta_{12} x_1 x_2 + \varepsilon$$

EXTENSIONS TO MORE REALISTIC SCENARIOS

- *New test scenarios*
- $Y = f^{(k)}(x;\beta)$

$$f^{(k)}(x;\beta) = \lambda_1 f^{(k-1)}(x_1;\beta_1) + \lambda_1 \underbrace{g^{(k)}(x_2;\beta_2)}$$

Effects of new factors in current stage

Test Design with Staged Development

- Do full operational testing and integration testing only after substantial stages.
- Do limited integration testing at intermediate stages at which modifications are small to moderate.
- Build in realism in developmental tests and carry out full component testing in developmental test.

Conclusion

- Test planning should be in the early stages of procurement
- Important features in test planning
  - procedures to be followed according to different test types (prototype development tests, sub-system tests, acceptance tests)
  - attandees to the tests
  - the criteria
  - evaluation
  - test reports
  - the conditions for the next step
- Test structure

Conclusion

- Evolutionary acquisition for procurement in defense systems
  - Evolutionary acquisition strategies
    - integrate advanced, mature technologies into producible systems that can be deployed to the user as quickly as possible.
    - match available technology and resources to approved, time-phased, capability needs.

Conclusion

- Testing is an important milestone for the procurement of unmanned vehicles
- A test center for unmanned vehicles
  - Repeatable test scenarios
  - Avoid loss of experience and knowledge

THANK YOU

Dr. Ebru SARIGÖL esarigol@stm.com.tr

Nuri M. ÇERÇİOĞLU ncercioglu@stm.com.tr

Dr. Anıl KAREL akarel@stm.com.tr

KAFKAS SOKAK NO:56 BEŞTEPE, 06510 ANKARA
TEL : +90 (312) 223 68 00 FAX : +90 (312) 223 68 18

www.stm.com.tr