IS T&E CHAOTIC?

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THE BEST LAID PLANS…..

- **An item of military equipment is needed to fulfill a requirement.**
- **A T&E planning effort is begun to plan for laboratory work, simulation runs, use of models, and operational field tests.**
- **The entire process is planned in a mathematically sound way in terms of cost, deliverables, contingencies, and requirements.**
- **HOWEVER, THE PROCESS IS NEVER COMPLETED AS PLANNED BECAUSE THINGS CHANGE AFTER THE INITIAL PLANNING EFFORT!**

WHAT COULD CHANGE?

- **Government cuts budget in half and also changes the requirements**
- **At the last minute, surrogate equipment had to be used in the field**
- **Error found in a model planned for use - a less detailed one is substituted**
- **Schedule accelerated because of a conflict in the world**
- **One of the tests reveals a major flaw in the concept**
- **A new technology is developed in the commercial sector that should be adapted**

WHAT DO YOU DO?

- **You re-run your test planning routines, resulting in a different plan**
- **You re-optimize the process and find that you were not on the correct course for the new circumstances**
- **You realize that this is going to cost money, time, and will add frustration**
- **You wish you had known at the outset that there were going to be changes**
- **You wonder about the scope of possible problems yet to come**

SO WHAT HAPPENED?

- **Is there anything wrong with the test planning routine?**
  - *PROBABLY NOT*
- **Could you have anticipated the particular changes that happened?**
  - *PROBABLY NOT*
- **Is this the first time that Military T&E plans have had to be changed?**
  - *CERTAINLY NOT*
- **Were you assuming the wrong T&E process model?**
  - *MAYBE SO*

WHAT IS NEEDED?

- **Traditional T&E planning procedures are designed for a static process, but the actual process is dynamic**
- **Formulate basic structure of the process:**
  - dynamical feedback - plans are modified repeatedly based on intermediate test results
  - process subject to internal and external influences
- **To make more realistic T&E plans study temporal behavior, instabilities, sensitivities, and correlations in the dynamical settings**

COMPLEXITY OF T&E

- **Some dynamic processes such as the stock market can be better modeled in a complex context**
  - T&E planning may be such a process
  - may need to apply the existing planning tools in a new and different way
- **What complex behavior might be present?**
  - chaotic? - sensitive to initial and boundary conditions
  - adaptive? - plans/problem definition change over time
  - hierarchical? - levels of structure; e.g. predictions are accurate for awhile then go chaotic again

STUDY OF THE BASIC T&E STRUCTURE

- **In progress (funded by all services via TEREC subcontract)**
  - Evaluate key structures of the T&E process
  - Suggest complex nature of process (or not)
- **Next step, if complexity indicated**
  - build a prototype model(s)
  - perform simulation experiments on them
  - refine models
  - develop methods for instability analysis
- **If complex and realized so, there are benefits**

BENEFITS OF RECOGNIZING A COMPLEX SYSTEM

- **Set achievable goals for T&E via more realistic test plans**
- **Improved predictability**
  - can trade-off shortening of the time horizon to still maintain prediction and control
  - can trade-off reducing the problem size to reduce complexity
- **Instabilities may not be a curse**
  - if you know it is chaotic, you can force small, but appropriate, changes early while still controllable

STUDY IN PROGRESS

FEATURES OF T&E THAT SUGGEST COMPLEXITY

- **Objective is to compare characteristics of known chaotic processes to T&E**
- **Infer what can happen**
- **Examples:**
  - extreme sensitivity
  - generalized catastrophes
  - failure of the scientific method

EXAMPLE #1 EXTREME SENSITIVITIES

- **Chaotic systems have arbitrarily large sensitivities to small variations in initial conditions, rendering them unpredictable**
- **Need to evaluate the T&E chaos-inducing sensitivities, identify nodes that amplify variations**
- **Unseen or uncontrollable external influences could cause the T&E process to deviate substantially from milestones or the completion time**
- **Fire in Taiwanese ceramic-glue factory causes jump in price of memory chips, precluding their use in the test's memory-intensive algorithm**

EXAMPLE #2 GENERALIZED CATASTROPHES

- **Chaotic systems have arbitrarily large sensitivities to small variations in boundary conditions and parameters, altering the qualitative nature of process**
- **Need to evaluate the catastrophe-inducing sensitivities, variations in plan structure and parameters that lead to major shifts in T&E process**
- **Change in plans or assumed parameters cause T&E process to deviate substantially from goals**
- **Moderate reduction in project budget crosses a threshold, below which solution strategy/technology simply cannot be used**

EXAMPLE #3 FAILURE OF THE SCIENTIFIC METHOD

- **Scientific method (hypothesize, predict effect, test experimentally, refine hypothesis, …) breaks down, prediction does not improve when it should**
- **Sensitivities/catastrophes possible in chaotic systems mean that important aspects of their behavior cannot be precisely predicted**
- **Chaos requires new approaches to globally (as opposed to exactly) analyze their behavior: e.g., look at the geometry and topology of state space structures**
- **Need a new view of T&E as a dynamical process**

PRELIMINARY INDICATIONS

- **Preliminary comparison to known chaotic systems indicate that the T&E process exhibits the instabilities and sensitivities of a chaotic process**
- **Simulation experiments are in order to**
  - confirm the indications
  - understand the process
- **All is not lost if complex - can develop a new procedure; may even realize benefits of being chaotic**
- **It is likely that existing planning methodologies and algorithms would continue to be used, to support a model of a new dynamic process**

NEXT STEP

COLLECT COMPONENTS OF SIMULATION EXPERIMENTS

- **Data Collection**
  - Review “classic” examples of times when events changed the T&E planning process
  - Review T&E processes that were completed
- **Select a planning process**
  - Test Plan Optimization Methodology(TPOM) is a good candidate for experiments (Logicon RDA, funded by OPTEC, Navy, Air Force)
  - it is algorithmic and reproducible
- **Select T&E scenarios and build prototype model(s)**

PERFORM SIMULATION EXPERIMENTS

- **Construct a simulation that is based on TPOM, introduce changes, re-optimize and assess**
  - the type of process that results
  - the scope of outcomes
- **Is it chaotic?**
  - evaluate predictability indicators
  - test for nonlinearity
  - measure strength of subsystem coupling
  - investigate the process drivers
  - evaluate unexpected consequences

THEN DO WHAT?

- **If it is not chaotic, then current methods are fine**
- **If it is, develop a better understanding of the process**
  - design controlled comparisons based on process parameters
  - evaluate some possible outcomes, especially extremes
  - investigate adaptive aspects with certain important process changes
- **Recommend a course of action for T&E planning**
  - procedure to identify system drivers
  - guidance for implementation of models

SUMMARY

- **T&E is a dynamic process**
- **Traditional T&E planning assumes a static process**
- **Indications are that it is also chaotic**
  - extreme sensitivities
  - generalized catastrophes
  - failure of the scientific method
- **Advantages of having correct process model**
  - more realistic plans
  - cost savings, increased accuracy
  - understand process

WORK NEEDED

- **Study in progress to determine indications of complexity**
- **If indicated**
  - couple past information and existing models
  - perform simulation experiments
  - understand the process
- **If complex, develop a new planning procedure that reflects the true process**
- **Brief T&E analysts on the practical consequences**