

US Special Operations Command



Agent-Based Simulation in an Integrated Analysis Process: An Example

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Date: 10 Dec 2007



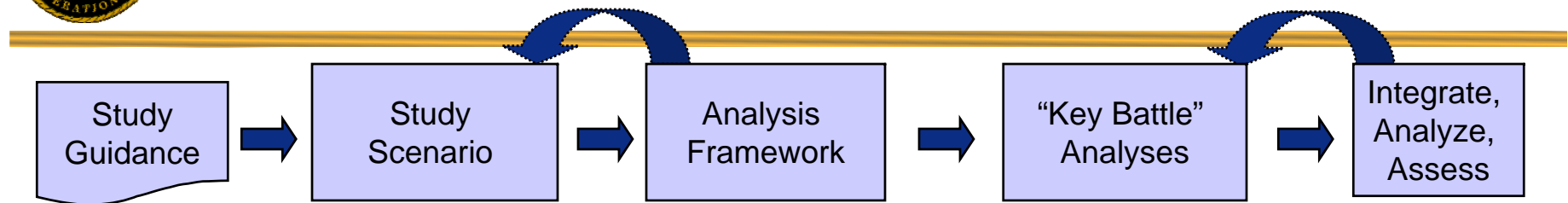
Outline

- **Integrated Analysis Process Overview**
- **Example Study Application of Process**
- **Key Components of Analysis Framework**
- **Focus on ABS Use in Framework**
- **Potential Irregular Warfare Extensions (CbT/COIN)**



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Integrated Analysis Process*



- Portrays process steps supporting typical study
- Study can produce an analytic baseline for follow-on strategic analyses
- Reflects decomposition of the problem domain into manageable chunks (the “key battles”)
- Loop-backs to run new key battle analyses
 - to examine planned excursions/emerging questions OR
 - to sequentially address campaign phases/opposing party moves over predetermined cycles (e.g., 60-day intervals)

* See back-up slides for additional process details

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Key Components of Analysis Framework in CWMD AB Study

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- Role player (SME) opposing party operational concepts*
- Wargame
- Agent-Based Simulation (ABS--Pythagoras)
- Simulation Experimental Design (for ABS)
- Mid-resolution intelligence, surveillance, reconnaissance (ISR) model (COSMOS)
- Low-resolution simulation (JAS)

* Expanding upon the details provided in the Multi-Service Force Deployment documents (MSFD) for the *Countering WMD Analytical Baseline (CWMD AB) Study*. [Note: Study name was changed on 14 Nov 07 from the *MCO-1 Catastrophic Study*]

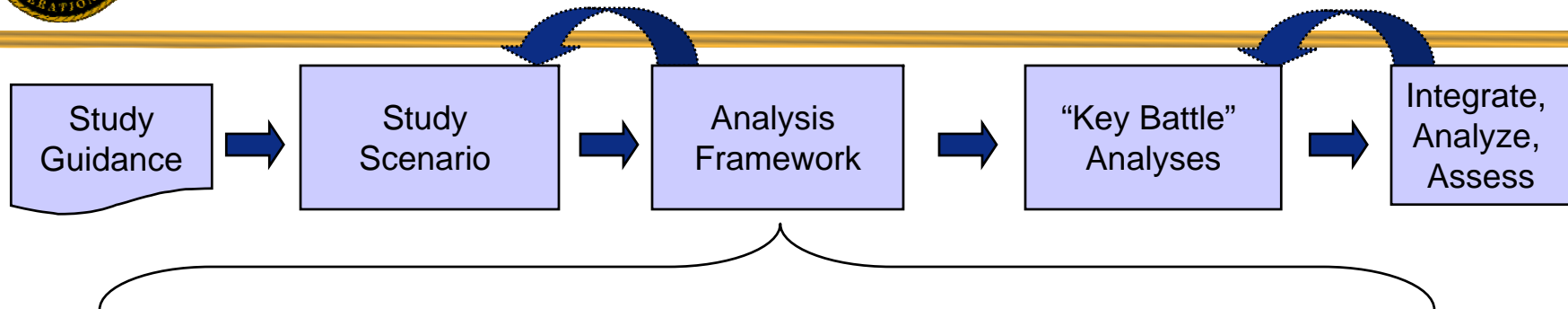
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Application of Wargaming (Example1)



In the CWMD AB Study (formerly the MCO-1 Catastrophic Study), a wargame (involving operational & functional SMEs & opposing party role players) was conducted “to derive data & alternative behaviors for an agent based model representation of unconventional warfare elements.” [LTC John R. Crino, USA, OSD PA&E, 75th MORSS Symposium abstract, *MCO-1 Catastrophic Study: A Loose Nuke Analytic Baseline Effort*]

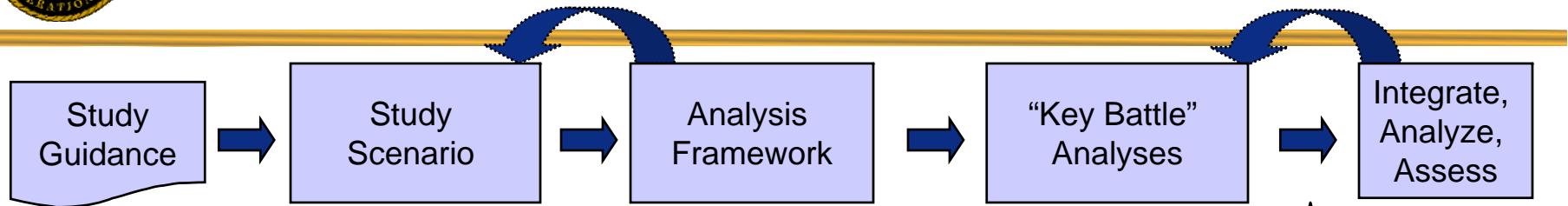
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Application of Wargaming (Example 2)



Ensuring Strategic Success Study Team employed periodic seminar wargame construct:

- Opposing party synchronization matrices (task organizations, missions, subordinate element tasks) for each of multiple areas of operation (AOs) in the country of interest.
- Simulated events over 60-day interval of campaign in AOs.
- Integrated results across AOs into country-level PMESII model.
- Opposing party role-players assessed results & made changes to synchronization matrices for subsequent 60-day interval.
- Mission analyses led to key battle scenario updates; scenarios run with new missions; PMESII model updated with results.
- Cycle continued over course of campaign.

[Operations Other Than War (OOTW) Flexible Asymmetric Simulation Technologies (FAST) Prototype Toolbox: Analysis Process, Para 4.6.1]

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CWMD AB Study Construct

- **From wargame (& follow-on SME interviews/guidance)**
 - Sets of potential events/situations (alternative conditions & opposing party operational concepts)
 - Likely opposing party event chains, behaviors & triggers
 - Agent attributes & system (sensor, weapon, comms device) characteristics
 - Likely outcomes & follow-on opposing party reactions
- **From ABS (Pythagoras)**
 - Stylized sets of specific event types reflected in experimental design of key design points.
 - Likelihood distributions of alternative behavior end-states (based upon 60-replication batches of each scenario variant).

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CWMD AB Study Construct-2

- **From C4ISR Space & Missile Operations Simulator (COSMOS): Probabilities of positive identification of targets over time & space by specific platform/sensor combinations**
- **From Joint Analysis System (JAS): Expected results relative to each target, given alternative courses of action, resource constraints, & likelihood data from Pythagoras & COSMOS.**



Why ABS in CWMD AB Study?

■ Situation

- Inability to simulate the whole study-level scenario at the high-resolution level.
- No reasonably available mid-to-high-resolution constructive simulation can address behavioral complexity of situations being addressed without being heavily scripted in entity actions or requiring lengthy/costly scenario development.
- Operational SMEs were extrapolating from recent operational experience with a different sort of high value targets.



CWMD AB Study ABS (Pythagoras) Approach

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- Scenarios structured to represent likely event/behavior chains of opposing parties under alternative conditions/situations to derive likelihood distributions of behavior end-states (target escapes, is rendered safe, self-destructs...).
- Simulation experimental design focused on design point combinations that should be discernible during the multi-day, country-wide simulation using the Joint Analysis System (JAS) → to select the appropriate likelihood distributions reflecting expected event outcomes.
- Resultant likelihood distributions then used in subsequent resource-constrained, multi-day integrated analysis.

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Extension to Irregular Warfare (COIN)

- Integrated analysis process construct originally developed for/tested in an OOTW/COIN environment (see FAST Toolbox use in *Ensuring Strategic Success Study* & subsequent toolbox documentation [available through MSCO]).
- Could simulate “key battles” along logical lines of operation described in FM 3-24, *Counterinsurgency* [MCWP 3-33.5]
- Could model changes in status of critical vulnerabilities of insurgents (FM 3-24) & PMESII systems of focus nation

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 - Operations analyst for the *Flexible Asymmetric Simulation Technologies (FAST) Project*
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Back-up Slides

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CWMD AB Study ABS (Pythagoras) Choice

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■ Why Pythagoras?

- Large number of user-defined alternative behaviors, leader-ordered behaviors, & corresponding behavior triggers can accommodate virtually any conceptual construct.
- Unique sets of agent & system characteristics in each alternative behavior.
- Functionality permits reasonable modeling of SME-expected entity (agent) interactions in the situations examined.
- Scenarios easily created/modified via GUI; batch sets of replications run quickly (60 replications in about 45 minutes on PC or laptop).
- Pythagoras Version 1.10.5 loaded on selected OSD PA&E & USSOCOM workstations; experienced modelers/analysts/SOF operators available/collocated at USSOCOM.

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ABS Process Model Construct

- **Why a process construct rather than model each expected situation?**
 - **Could not forecast every specific event location & condition that would be observed in the integrated analysis phase.**
 - **Operational SMEs could describe behavior/event chains of the contending parties.**
 - **Stylized interacting event chains would map well to terminal behavior states of interest & simulation experimental design.**
 - **Expected substantial variability in entity behaviors/situations:**
 - Targets could select/take many alternate routes.
 - Targets could respond differently to being detained, delayed, engaged.
 - Varying sequences of sensor queuing could occur, with or without human intelligence providing initial target information.
 - Decoys & false targets would compound the positive identification issue.



Pythagoras Strengths & Limitations

■ Strengths

- Flexibility in modeling abstract concepts
- Ease/speed of scenario development
- Ability to visualize, pause & drill down to check agent status during simulation runs in play-forward mode.
- Ability to quickly data farm over scenario inputs



Pythagoras Limitations

■ Limitations

- **Current release (Version 1.10.5) not compatible with latest Java releases (6.1 & higher)—Version 2 under development to fix this**
- **Formal validation/invalidation process still under development**
- **User must accommodate to agent movement logic (instantaneous hopping to projected location at next time step): medium resolution of travel distances per pixel can negate detections/engagements potentially occurring at shorter time steps**
- **Without data farming capability (not used in CWMD AB Study), cannot determine precisely which input values were used for a particular replication without greatly expanding the experimental design & replacing the variable soft rule tolerances with fixed values**



ABS Use Considerations in CWMD AB Study

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- **Construct generalized to accommodate reasonable ranges of input data values (since real-world values, e.g., target behavior triggers, not known with certainty in some cases); assumed Uniform distributions over those ranges.**
- **Likely contending party behaviors of greater interest than need to precisely model system characteristics at the engineering level of detail (scenario inputs were calibrated to produce reasonable results—keyed to SME expectations & sensor-to-target PID probabilities).**

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Extension to Irregular Warfare (Combating Terrorism)

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- **Could reflect resultant behavior tendencies of selected target audiences & subsequent impacts on focus nations**
- **Could represent direct & indirect effects**
 - of contending parties seeking to defeat/disrupt versus support/enhance violent extremist organizations (VEO)/networks
 - by modeling changes in potential over time & space for
 - the PMESII systems of the focus nation &
 - the nine VEO critical capabilities in the Counterterrorism Analytical Framework (CTAF)*

* USJFCOM, Information Superiority Group, Standing Joint Force Headquarters has an unclassified presentation on *PMESII-T Systems Considerations*, which maps the CTAF components of terrorist networks through a host nation PMESII analysis to an operational environment (employing holistic systems perspective).

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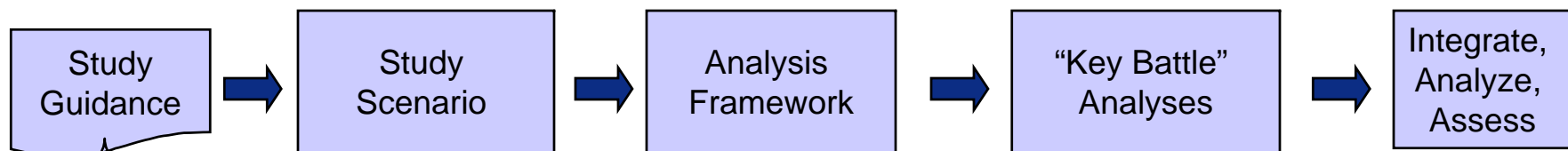
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Integrated Analysis Process



- DPS/MSFD
- TOR
- Plan of Analysis
- Scope
- Assumptions
- Products
- Timelines

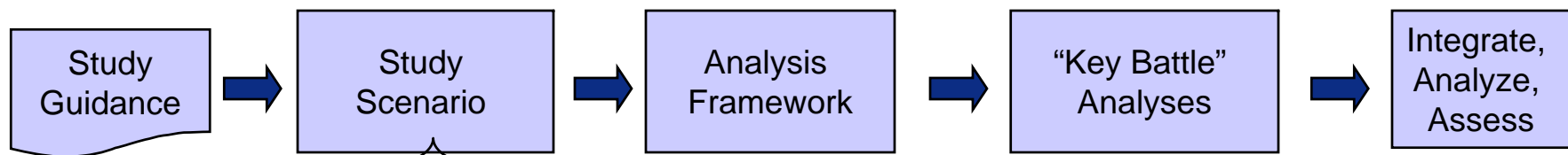
- Portrays process steps of typical study.
- Study can produce an analytic baseline for follow-on strategic analyses.
- Reflects availability of an approved Defense Planning Scenario (DPS) & complementary Multi-Service Force Deployment Document (MSFD).
- Study terms of reference (TOR) document explains where/if study scenario will deviate from the DPS/MSFD.

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Integrated Analysis Process



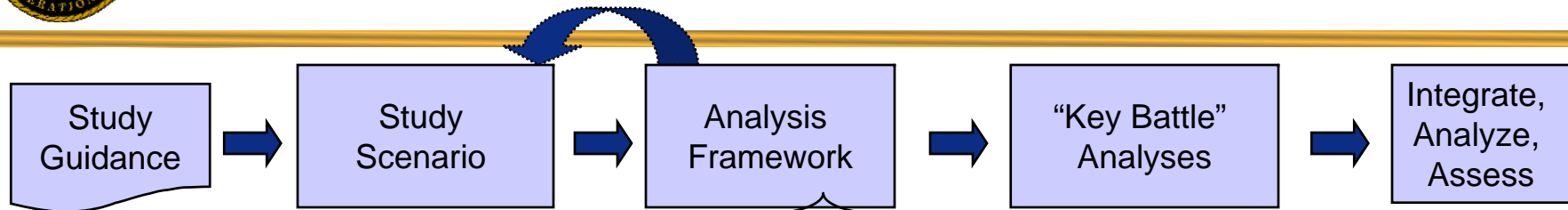
- **DPS/MSFD extraction & adjustment**
- **Added assumptions**
- **Forces/contending parties (task org, missions, objectives, relationships)**
- **“Road to War”/starting conditions**
- **Base Case/planned excursions**

- **Scenario development builds on the DPS/MSFD.**
- **Study’s focus likely requires development of greater detail than provided in DPS/MSFD at levels below the Joint Force.**



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Integrated Analysis Process



- ID "key battles"
- ID/create applicable MS&A tools
- Map tools to "battles"
- ID/create integrating steps/mechanisms to
 - ✓ Address voids
 - ✓ Perform analysis
 - ✓ Pass results
 - ✓ Integrate results
- Plan for verification & validation throughout

- A decomposition of the problem domain into manageable chunks (the "key battles"), since a single model does not exist that can incorporate all of the required elements. [Adapted from Chapter 2, *Operations Other Than War (OOTW) Flexible Asymmetric Simulation Technologies (FAST) Prototype Toolbox: Analysis Process*]
- Scenario refinement/added data development likely required.

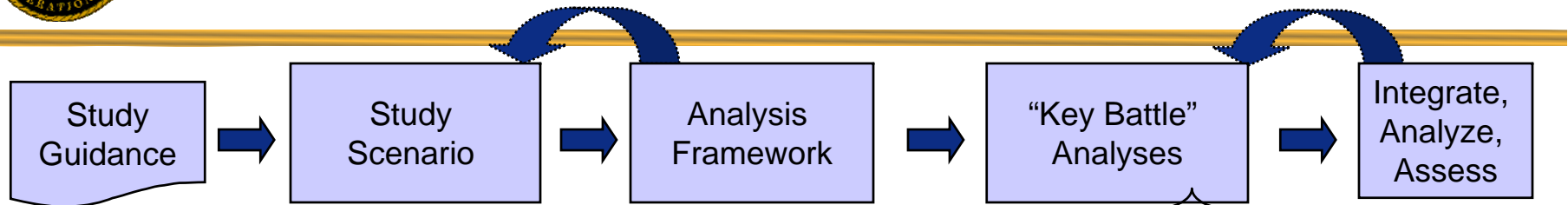
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Integrated Analysis Process



Considerations/tradeoffs:

- Data availability
- Resources/time available
- Resolution required
- Fidelity required
- Needed output detail
 - ✓ Insights
 - ✓ General likelihoods
 - ✓ Expected values

- Eventual fit/linkages among separate "key battle" analyses hard to predict at the beginning.
- Time, resources must be planned to accommodate workarounds, develop pre-/post-processing utilities that were not envisioned at the start .

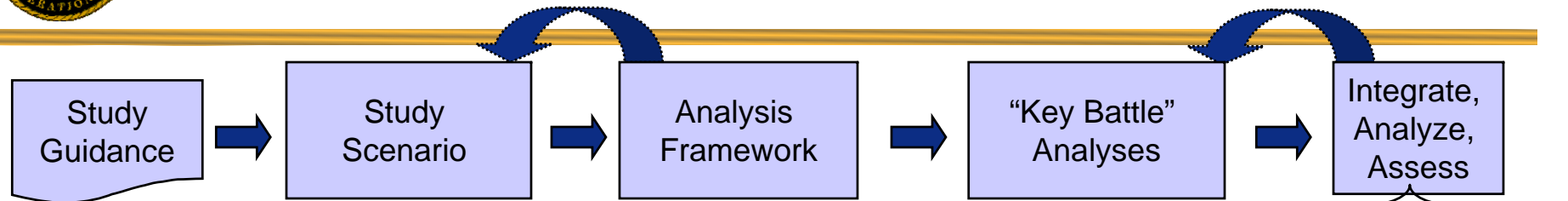
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Integrated Analysis Process



- Extend to campaign/operation level & duration(s)
- Apply SME/ role player judgment on resource allocation & party relationship changes
- Cycle as needed
- Document results & report

- Looping back through “key battle” analyses needed if integrated analysis produces insights/questions that merit further exploration (OSD PA&E “CWMD AB Study” took this form—each cycle addressing multiple days of events at the country level).
- A cyclical form of the framework is appropriate if key battles feed a campaign/operation phase or time step at the integrated analysis level & role player decisions necessitate changes in the key battles for the next phase/time step (JS J8 “Ensuring Strategic Success Study” form—each run simulating a 60-day interval within several months of a campaign).