Boundary Flow Modeling (BFM)

Security Policy, Architecture, and Behavior Modeling for Distributed Systems

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The Message

Boundary Flow Modeling describes security characteristics in terms of data flow histories at element boundaries.

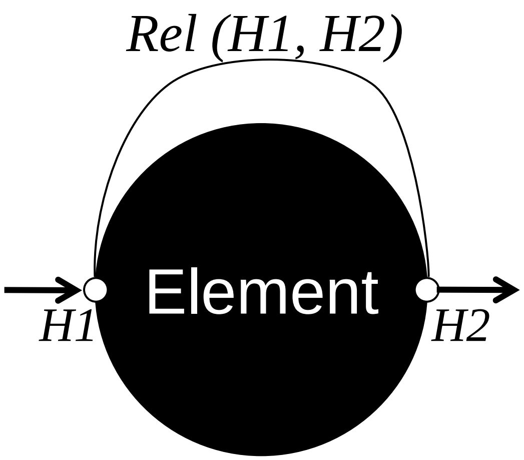
We have shown this method to be effective for distributed systems.

Contents

- Boundary Flow Modeling, Briefly
- Some Identified Security Modeling Needs + Characteristics of a Solution
- BFM Methods and Examples
- How BFM Meets the Identified Needs
- Current BFM Evolutionary Developments

BFM, Briefly

- Characteristics that BFM models
  - Policy (security requirements)
  - Architecture (high level design)
  - Behavior of elements (system, subsystems, components), viewed as black boxes
- The key of understanding BFM
  - The "words" in the modeling "language" are: histories of data flows across external interfaces of elements
  - The "sentences" are: logical relationships among histories
  - The "stories" are: inferences among relationships



Identified Security Modeling Needs

- Primary need:
  Modeling policy, architecture, and behavior
  of distributed systems
- Related need:
  Addressing the security composition problem
- Solution characteristics—a solution would have to:
  - Provide a black box view of individual targets.
  - Provide an alternative to state modeling—
    models need to be in terms of external boundaries.
- We propose that BFM is such a solution.

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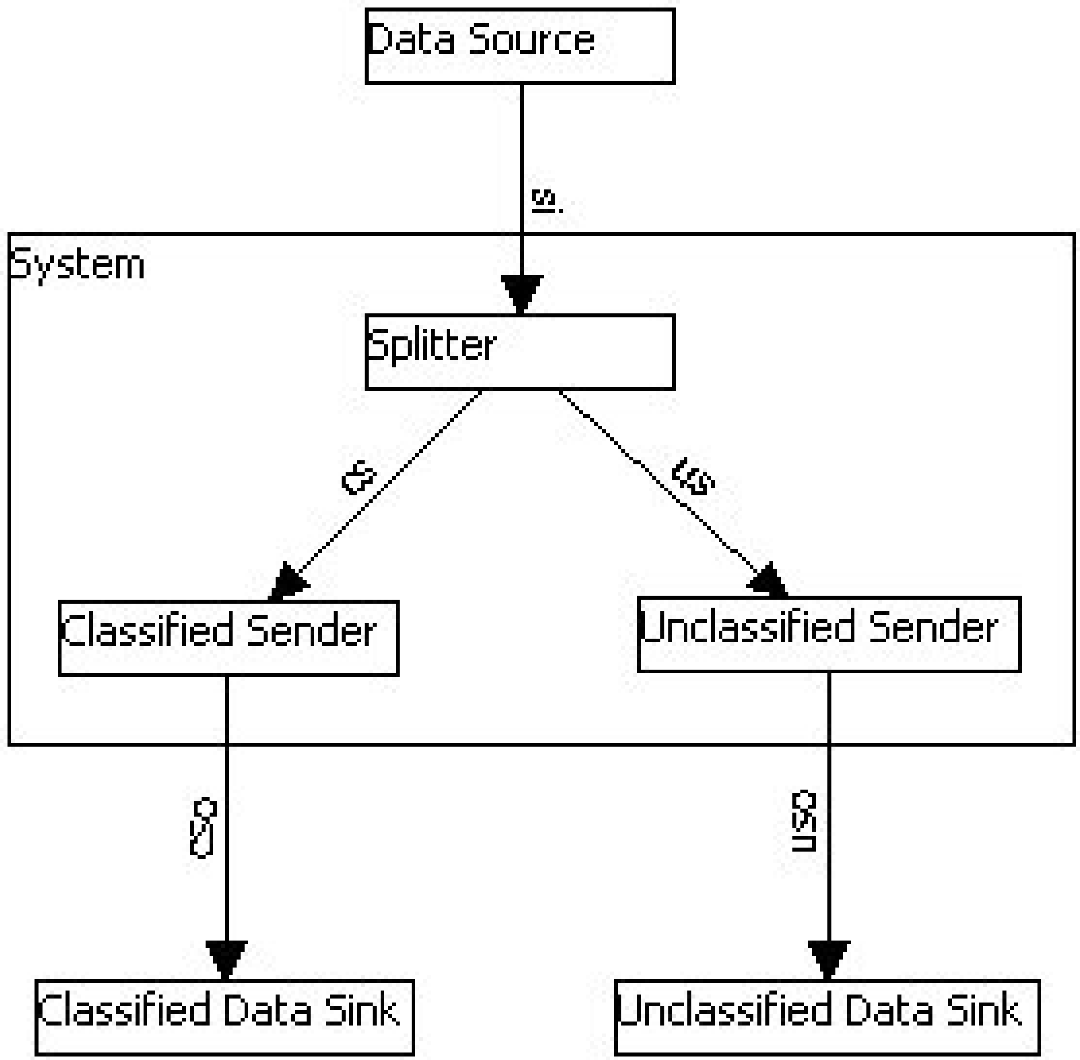
Detailing the BFM Process

- Define an example:
  Data Sorter, a simple (distributed) system
- Walk through the process:
  Perform the steps of the process on the example.
- Identify “real” examples:
  Systems we addressed with BFM

A Simple Example: Data Sorter

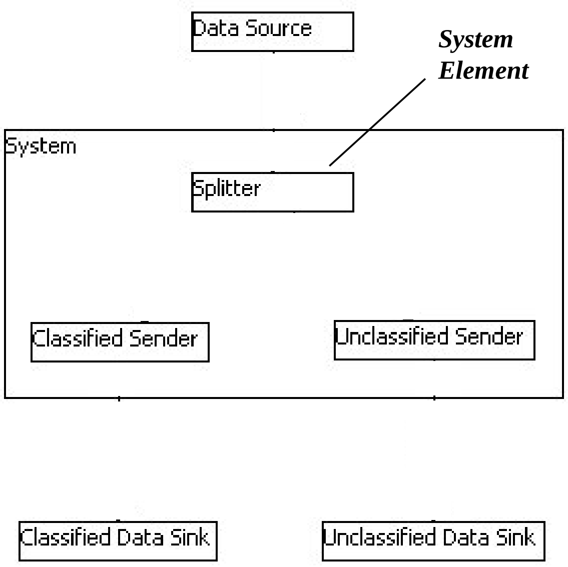


The Process

Diagram of Phases

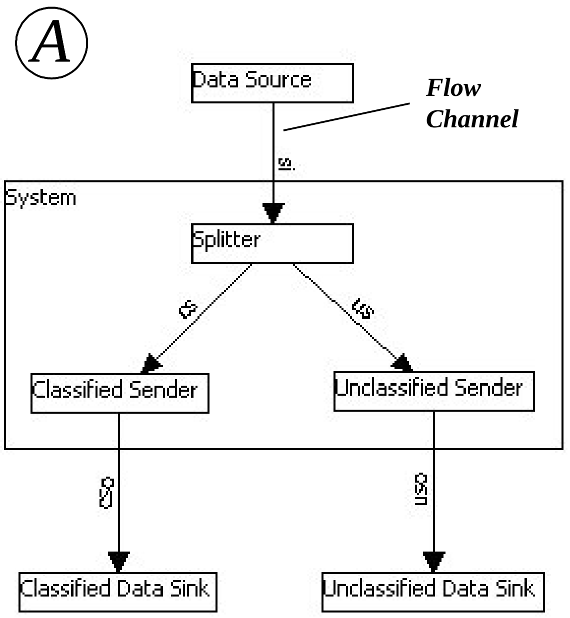
Phase 1

Security Architecture
Structure Modeling...



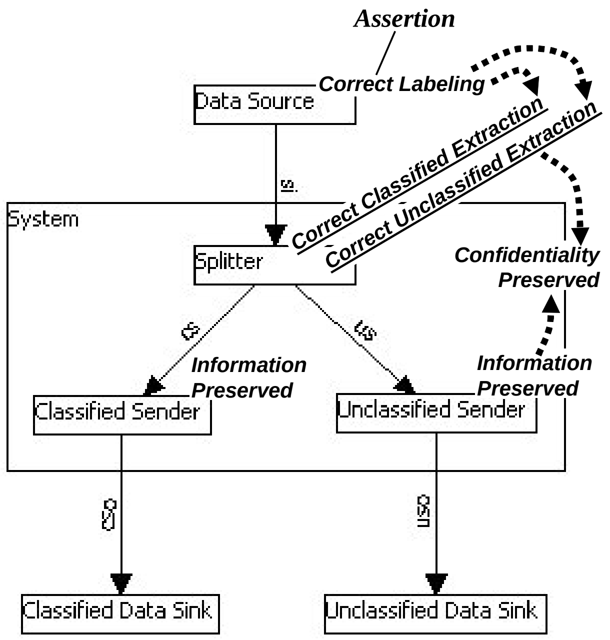
Phase 2

...Enhanced by
Information Flow...



Phases 3 & 4

...with Chain-of-Logic
Assertion Dependencies



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Phase Details

- *Phase 1*: Express the architecture
  Elements and component relationships
- *Phase 2*: Interfaces and data flows
  Expressed in terms of histories at interfaces
- *Phase 3*: Security constraints/behavior
  Expressed as relationships among histories
- *Phase 4*: Inferences among relationships
  Element assumptions in terms of assertions of component and peer elements
- *Phase 5*: Chain of Logic
  Applying *modus ponens* to the inferences: Validating system policy from leaf elements

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“Real” Examples—Actual Systems

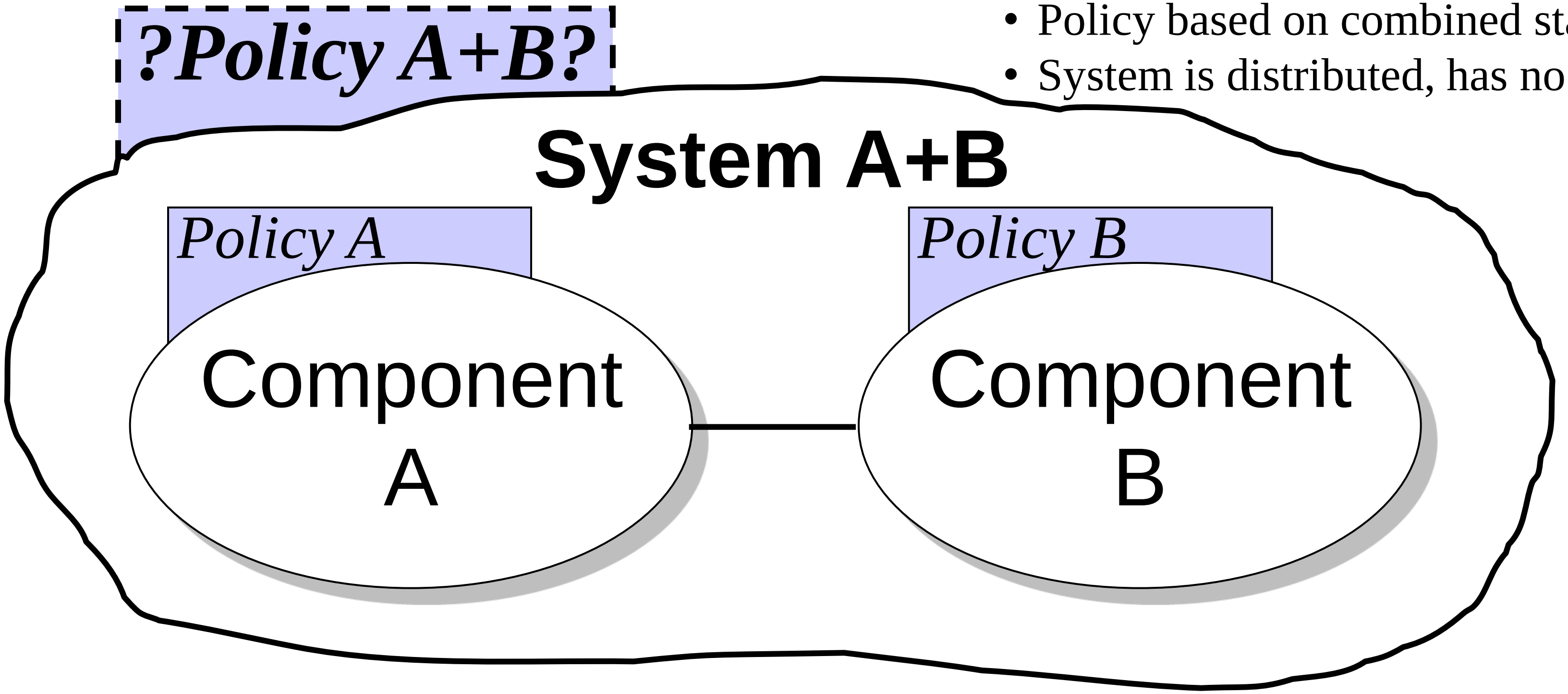
- Multinet Gateway and network environment
  - MLS network gateway (RADC and NSA)—1985-1990
- File Server example
  - Formal design modeling to validate Gypsy environment (Current Endorsed Tools List Example—National Computer Security Center (NCSC)—1991)
- F-22A Weapon System architecture and platforms
  - (Air Force—1992-1999)
- Joint Simulation System (JSIMS): Warfighter Training System
  - Two-enclave modeling and simulation system (joint sponsorship—1999-2001)

Does BFM Meet the Identified Needs?

- Solution characteristics
  - Statement: black box view of element modeling
  - Statement: modeling in terms of interfaces, not state
  - Conclusion: BFM has these characteristics
- Primary need
  - BFM models policy, architecture, and behavior of elements.
  - BFM is appropriate for distributed systems. (permits nondeterminism)
- Related need
  - BFM approach addresses the composition problem.

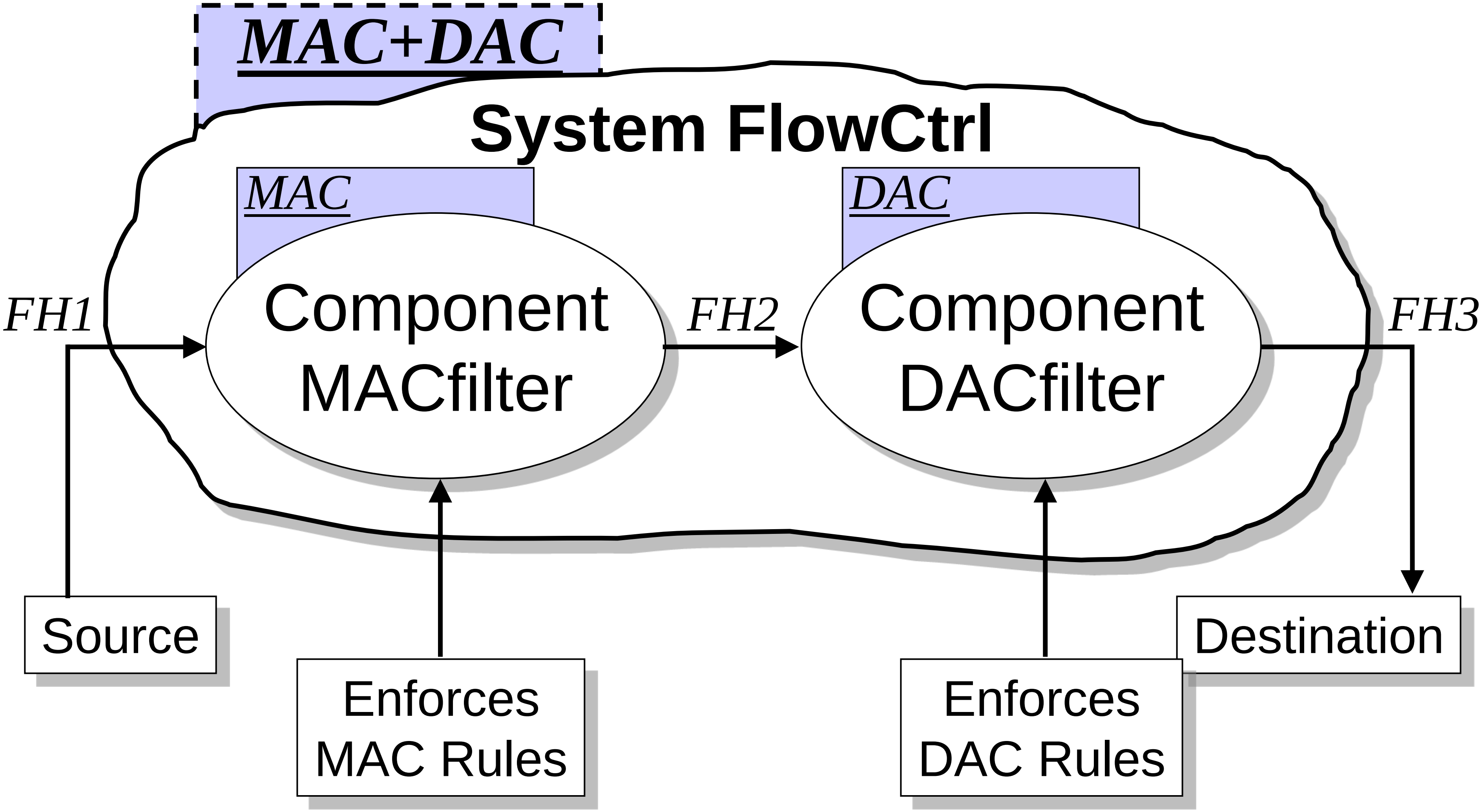
A Statement of the Security Composition Problem

- Policy based on combined state, *or*
- System is distributed, has no state



"If you have two components, each with a security policy, what is the policy enforced (if any) when the two components are combined?"

Making Sense of Security Composition



Composition Example Policies in BFM

- *MAC* Policy:
  Every packet in *FH2* has the same content as a packet in *FH1* with the MAC rules satisfied.
- *DAC* Policy:
  Every packet in *FH3* has the same content as a packet in *FH2* with the DAC rules satisfied.
- *MAC+DAC* Policy:
  Every packet in *FH3* has the same content as a packet in *FH1* with both the DAC rules and the MAC rules satisfied.
- To demonstrate based on system architecture:
  MAC Policy **AND** *DAC* Policy
  IMPLIES *MAC+DAC* Policy

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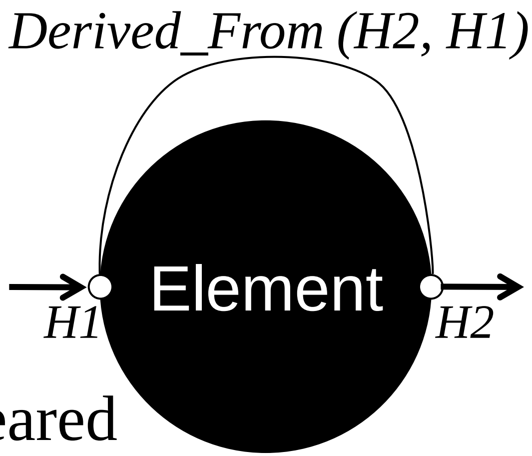
Current BFM Evolutionary Development

- Soundness of flow history relationships
  - Issue of logical soundness of flow history relationships for separated elements
- Integrating BFM and state models
  - Value and approach of model integration within distributed systems
- Tool support for BFM
  - Need, past attempts, and plans

Soundness of Flow History Relationships

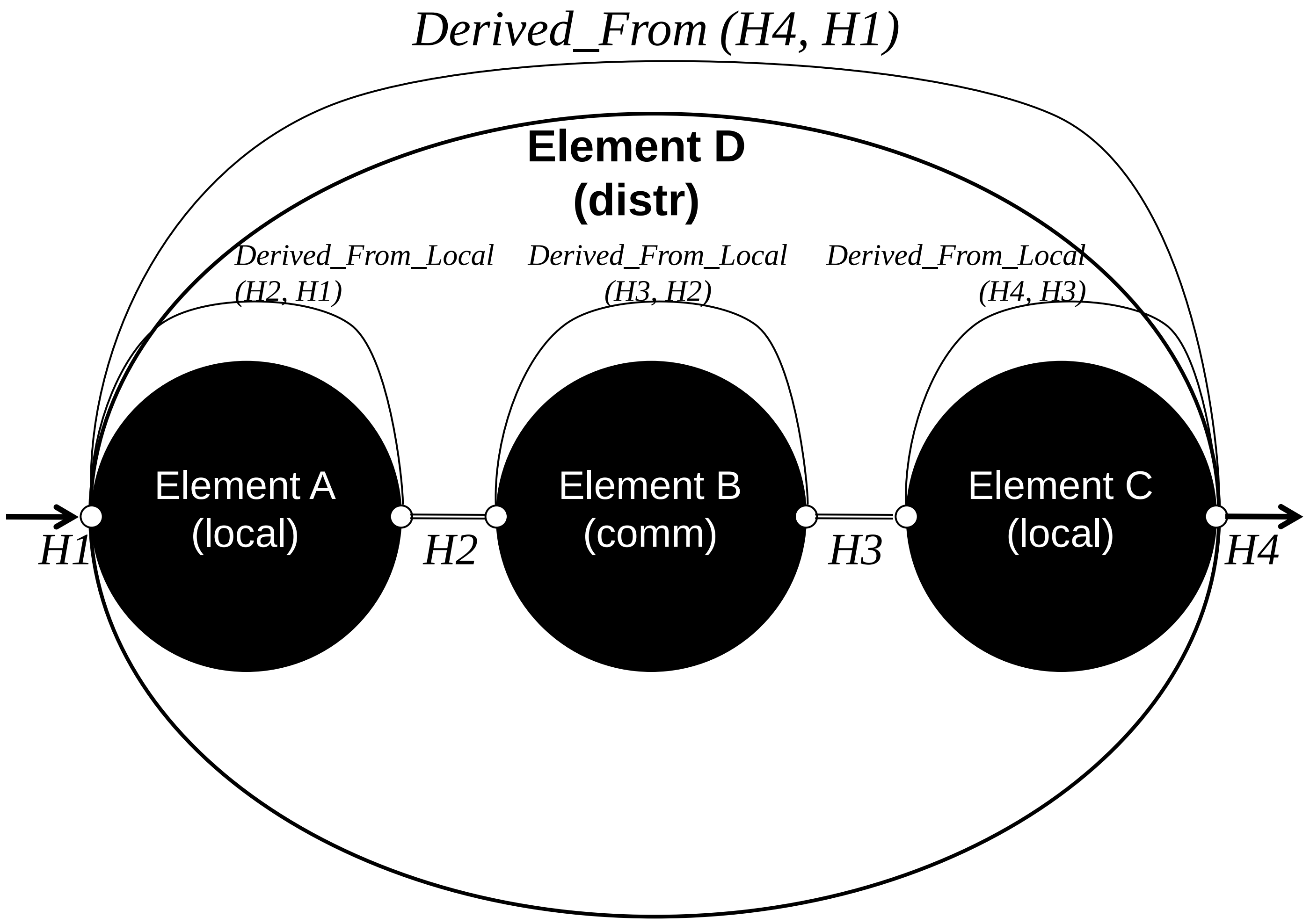
- The Pitfall
  - It's easy to end up with unsound statements.
  - Key issue: inadvertent assumption of a system-wide time referent—not a problem with "local" elements
  - Past use of "oracle functions" has defied detailed definition:
    For every entity *e2* in *H2*
    there is an entity *e1* in *H1*
    such that *e1* = *e2*
    (This ignores that *e1* may have appeared after *e2*, while we are trying to make *e1* account for *e2*!)



  - We can stay with a "mushy" definition of *Derived_From*, but that defeats any but the most minimal assurance.

Soundness of Flow History Relationships (2)

- The Plan—supporting diagram



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Soundness of Flow History Relationships (3)

- The Plan
  - Elaborate *Derived_From* based on a “local” element function *Derived_From_Local* .
  - This new function is applicable only to architecturally local elements, within which time is definable.
  - *Derived_From_Local* time orders all history entities appearing at its external interfaces.
  - Given the local time ordering, by which history entities have been locally time stamped, *Derived_From* associated with higher level elements (containing the related local elements) can express sound accountability relationships.
  - Remaining question: when can a communications channel be considered a local element?

Integrating BFM and State Models

- The Issue
  - Some (local) elements are best modeled using a state approach.
  - But distributed systems and subsystems need to be modeled using BFM.
  - Therefore, for a complete system security integration, the two modeling schemes must be coordinated.

Integrating BFM and State Models (2)

- The Status and Plan
  - A successful experiment:
    - Restating the GWV (state-based policy) of a separation kernel (SK) in BFM
    - Demonstrating that the BFM statement of the policy is true whenever the GWV statement of the policy is true
    - Result: The BFM scheme can validly use the claim of BFM form of the SK policy to contribute to inferring the policy of an element that contains the SK.
  - To be done
    - Perform similar experiments in other contexts (e.g., the state model of an entire platform).
    - Obtain community review of these experiments.

Tool Support for BFM

- The Need
  - Efficiency in the modeling process
  - Presentation of the model to developers, reviewers, and customers
  - Accurate validation of the model

Tool Support for BFM (2)

- The Accomplishments
  - Developed an XML-based tool.
  - The tool:
    - Accurately represents the model.
    - Allows (more-or-less) convenient capturing of model data.
    - Supports model validation.
    - Supports (marginal) graphical presentation of the model.
  - Applied the tool to a number of modeling tasks.
- Plan
  - Assess commercial tools (most are based on UML) for feasibility of add-ons to support BFM process needs.
  - Implement the add-ons and apply to modeling tasks.

CONCLUSIONS

- BFM is a feasible modeling scheme.
- BFM is workable in a number of contexts.
- BFM can be integrated with other modeling schemes.
- Claim: With adequate tool support, BFM can be used to provide necessary security assurance within production system development.