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Complex Adaptive System of Systems (CASoS) Engineering Initiative
http://www.sandia.gov/CasosEngineering/

Application of Complex Adaptive Systems of Systems Engineering to Tobacco Products

Theresa Brown

Nancy Brodsky
Arlo Ames
Bob Glass

Pat Finley
Tom Moore

John Linebarger
Aldo Zagonel
Louise Maffitt

Sandia National Laboratories
Albuquerque, NM

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Why examine tobacco use?

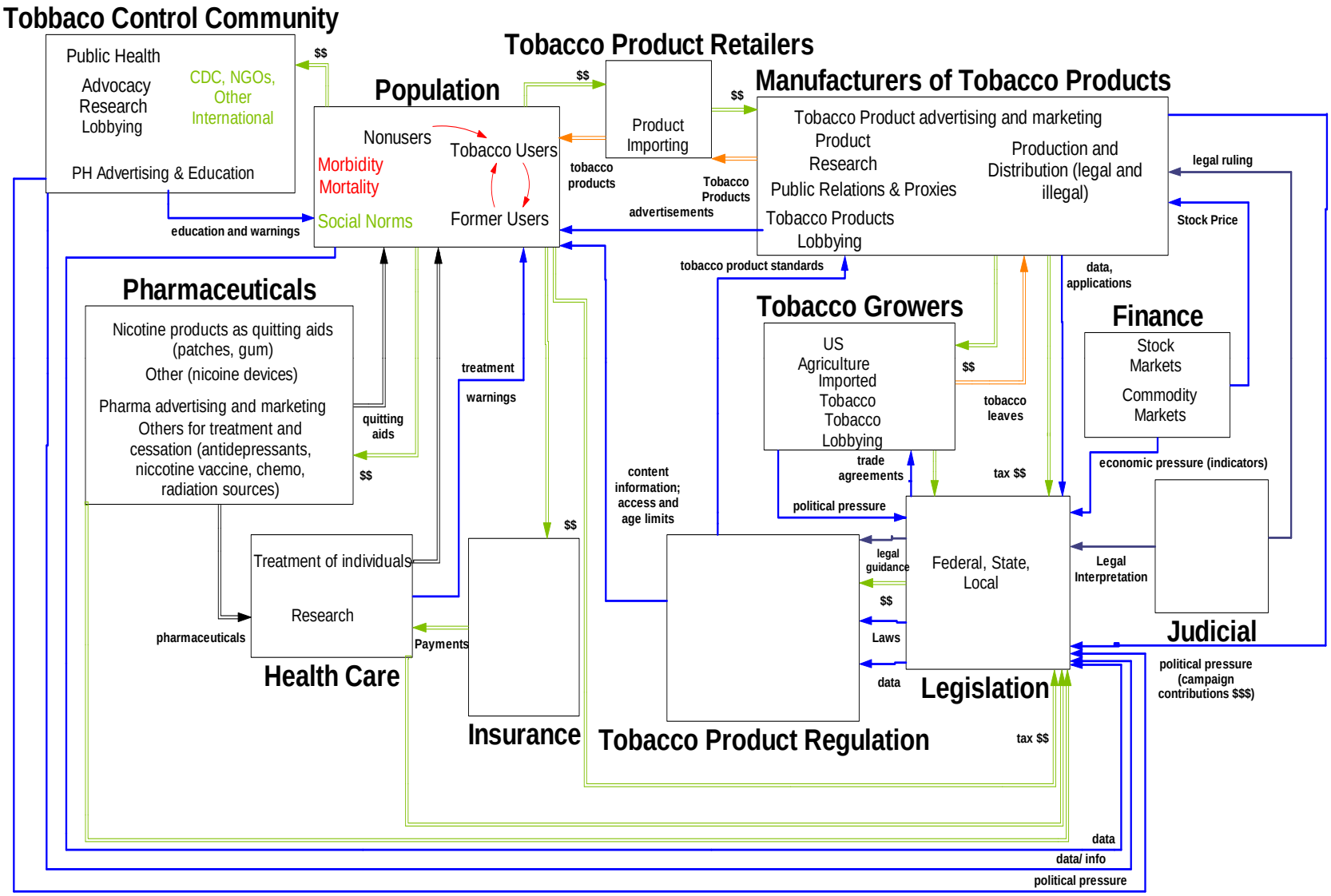
- Significant Problem:
  - Cigarette smoking is the leading preventable cause of death in the United States: tobacco-related illnesses are responsible for 443,000 premature deaths each year [CDC 2008, CDC 2002]. Smoking rates for U.S. adults have declined since the mid 1960s, but rates of decline have diminished in recent years.
- Exemplifies a Complex System: Tobacco use exists within a set of interwoven and evolving personal, social and economic systems.
  - Social networks, cultural and familial associations, personal identity, physical addiction.
  - Tobacco industry is provides jobs, U.S. GDP, tax revenues.
  - The tobacco control and regulation communities seek to reduce harm caused by tobacco use through advocacy, education and regulatory oversight; their challenge is to act effectively.
- Can we influence a CASoS in socially beneficial directions?
  - Generating conceptual models of the system can help define achievable aspirations for influencing the tobacco products CASoS. These aspirations can be mapped to interventions specifically designed to influence the tobacco products CASoS in a direction that lowers mortality, morbidity and costs associated with tobacco use.

Tobacco Products Exist Within Larger Socio-Economic-Technical System

- Entities: Who are the relevant entities? (not a comprehensive list)
  - The public (smokers, non-smokers)
  - Product growers and manufacturers
  - Government entities (gov't offices that collect and use taxes, regulators, health monitors/advocates (e.g.,CDC, NIH)
  - Health care providers
  - Insurers
  - Retailers
- How are the entities connected, how do they influence one another?
  - Goods
  - Money
  - Services
  - Information
  - Social networks
- Is there adaptation of entities and connections?
  - Changing tobacco technologies (low-nicotine products, electronic cigarettes)
  - Cycle and progression of regulatory and industry adaptations.
  - Changing social norms

CASoS Engineering

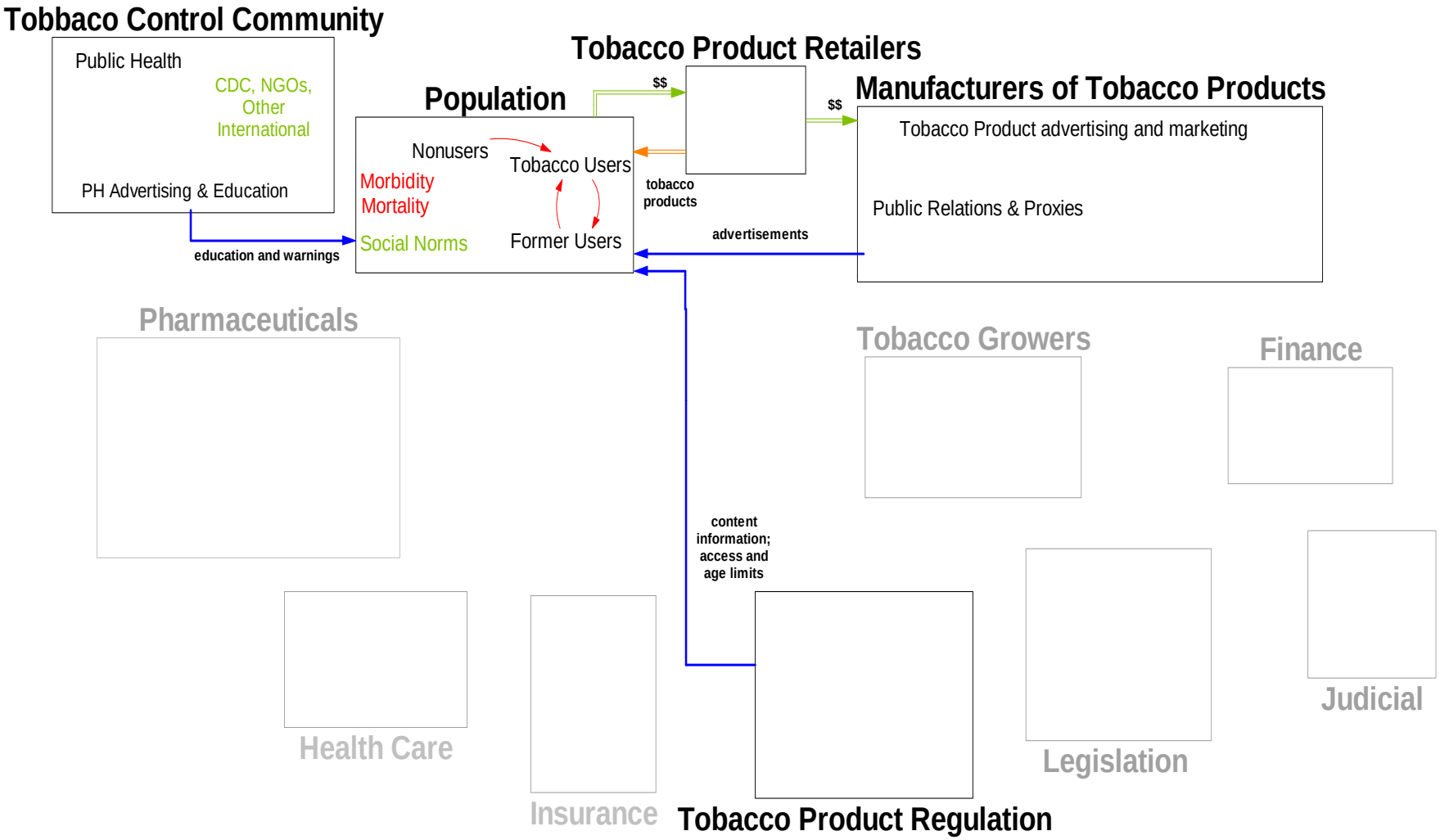
Tobacco Product Systems of Systems



Tobacco/Nicotine Subsystem Diagram

All policies affect population, either directly or indirectly

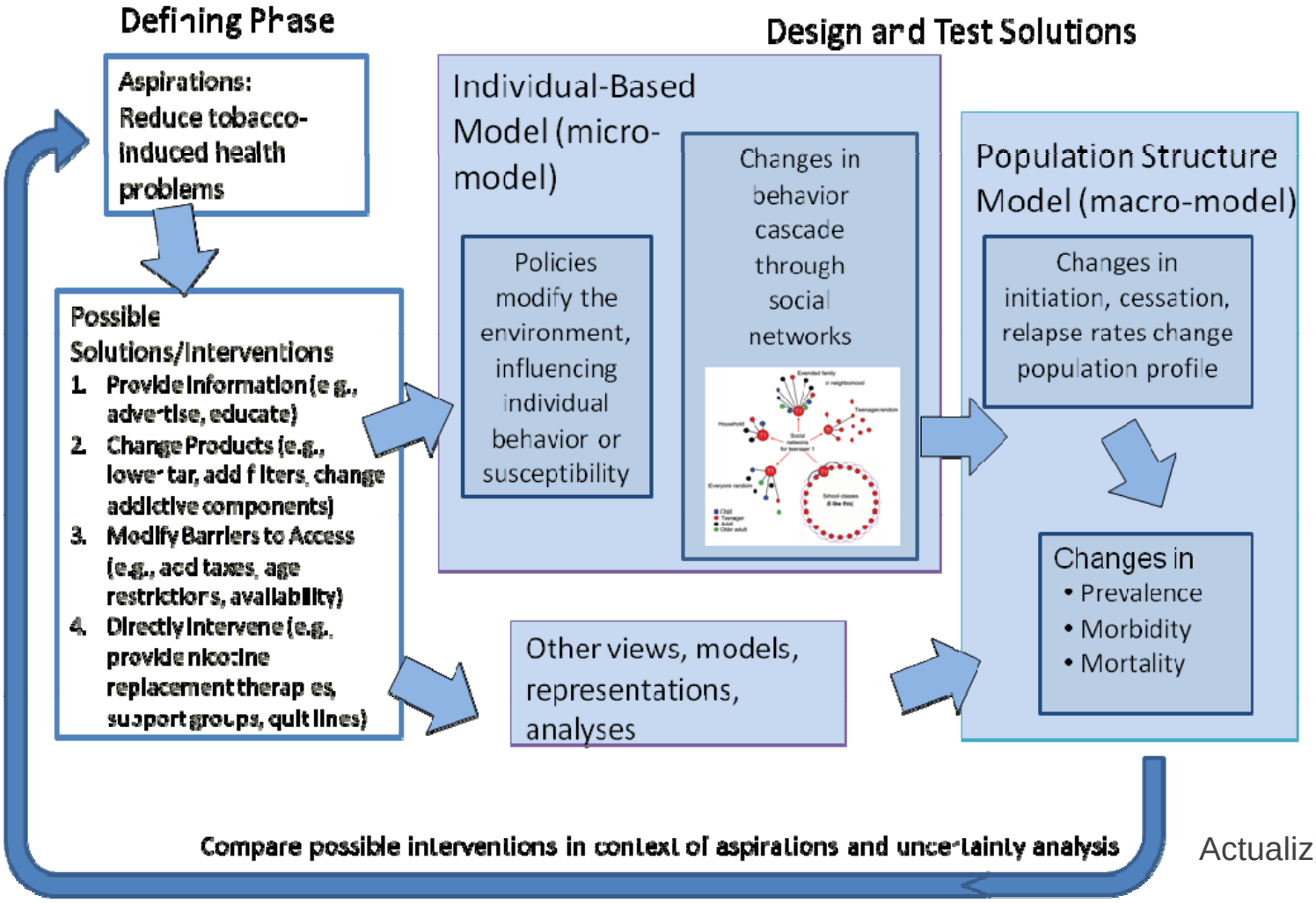
Current Analysis Development



Define Aspirations:

What policy options would be most effective for reducing tobacco-induced morbidity and mortality?

Application of CASoS Process to Tobacco



Ranking of Individual and Combined Policy Options

- Baseline
  - Best estimates of parameters based on most accurate information or expert opinion
  - Identifying outcome metrics (values, distributions, combinations (integrated measures))
  - Evaluating metrics used for ranking actions and combinations of actions (policy components)
  - Initial policy comparisons
- Incorporate Parameter Uncertainty
  - Parameter value distributions
  - Analysis of model output
  - Ranking actions and action combinations
    - Have rankings changed? What are specific effects?
    - Is there a clear policy choice? Robust to uncertainty? Robust to different integrated measures?
    - What data or model refinements would make choices more clear?
    - Are there critical enablers for system adaptation to changing environmental, social, and product development factors?
- Incorporate additional uncertainties and measures
  - How can we achieve conditions that will be needed (e.g., how effective does education need to be)?
  - Incorporate model uncertainty (uncertainties in model structure, assumptions, formulations, weights). Do measures' values change? Does ranking change?
    - Results differ for different models
    - Results dependent upon different assumptions of basic behaviors (e.g., rational/irrational behaviors)
    - Results dependent upon social network interactions, initial networks

Summary

- Value of CASoS Engineering Framework
  - Aspirations guide the process, from system definition to evaluation of actualization.
  - All subsystems are relevant to the problem, some are more relevant to our chosen aspiration.
  - Aspirations allow focus on core aspects of system behavior. Then build out analysis as necessary.
  - Uncertainty analysis allows identification of solutions that are robust
- Value of Models
  - Social network influence on tobacco use and effectiveness of interventions
  - Identifying and understanding the dynamics
  - Differentiating impacts on population health (timing, distribution, magnitude and duration)