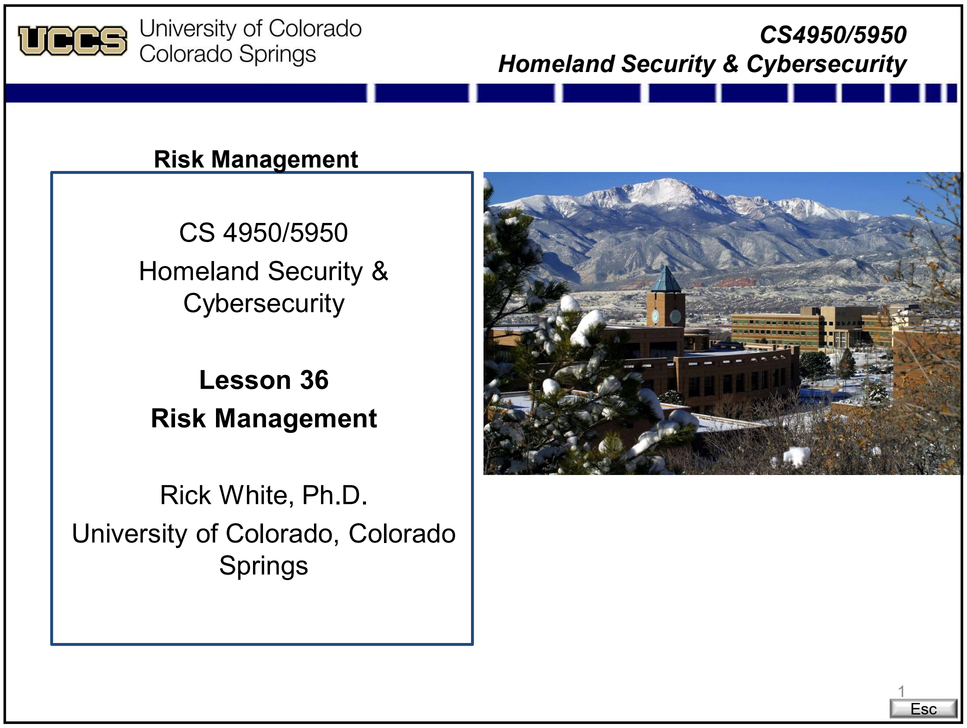

Risk Management

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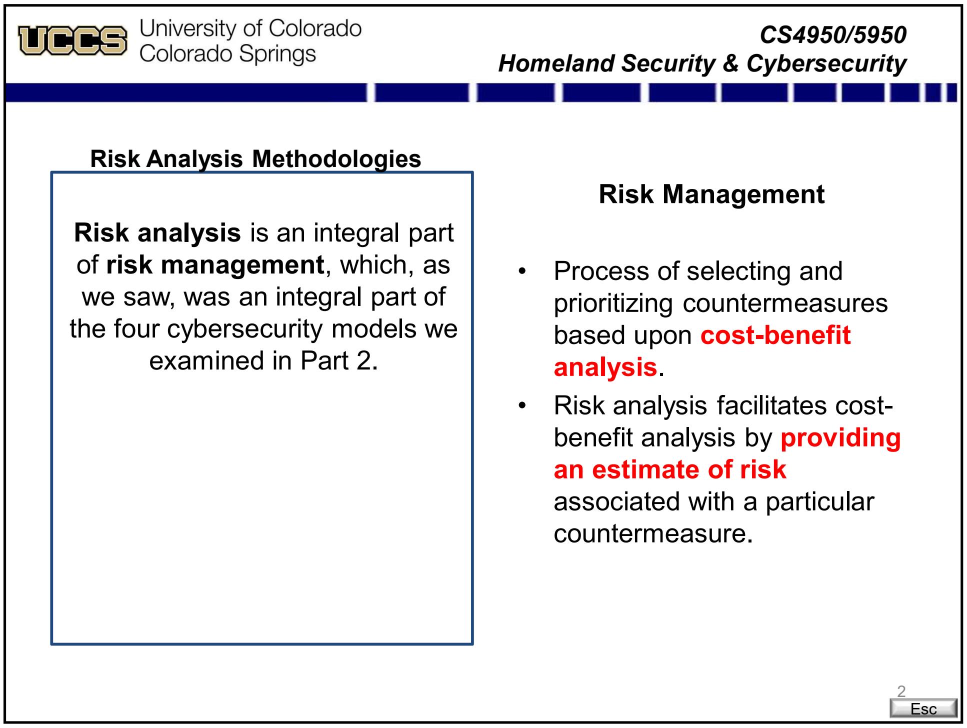
Lesson 36
Risk Management

Rick White, Ph.D.
University of Colorado, Colorado Springs

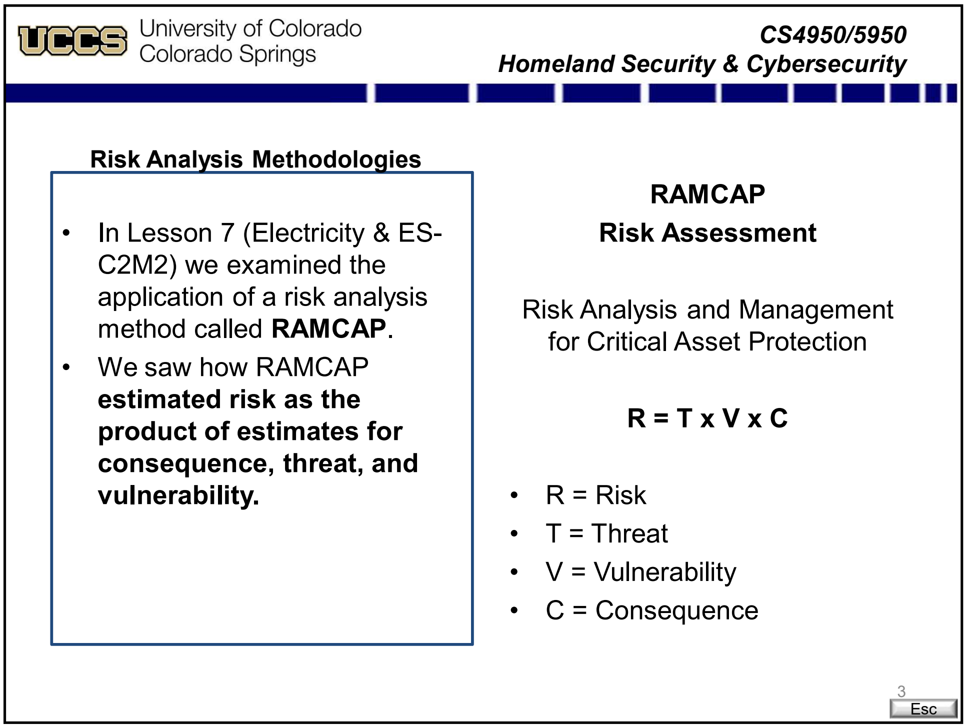


Risk Analysis Methodologies

Risk analysis is an integral part of **risk management**, which, as we saw, was an integral part of the four cybersecurity models we examined in Part 2.

Risk Management

- Process of selecting and prioritizing countermeasures based upon **cost-benefit analysis**.
- Risk analysis facilitates cost-benefit analysis by **providing an estimate of risk** associated with a particular countermeasure.



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Risk Analysis Methodologies

- In Lesson 7 (Electricity & ES-C2M2) we examined the application of a risk analysis method called **RAMCAP**.
- We saw how RAMCAP **estimated risk as the product of estimates for consequence, threat, and vulnerability.**

RAMCAP
Risk Assessment

Risk Analysis and Management for Critical Asset Protection

R = T x V x C

- R = Risk
- T = Threat
- V = Vulnerability
- C = Consequence

3

Esc

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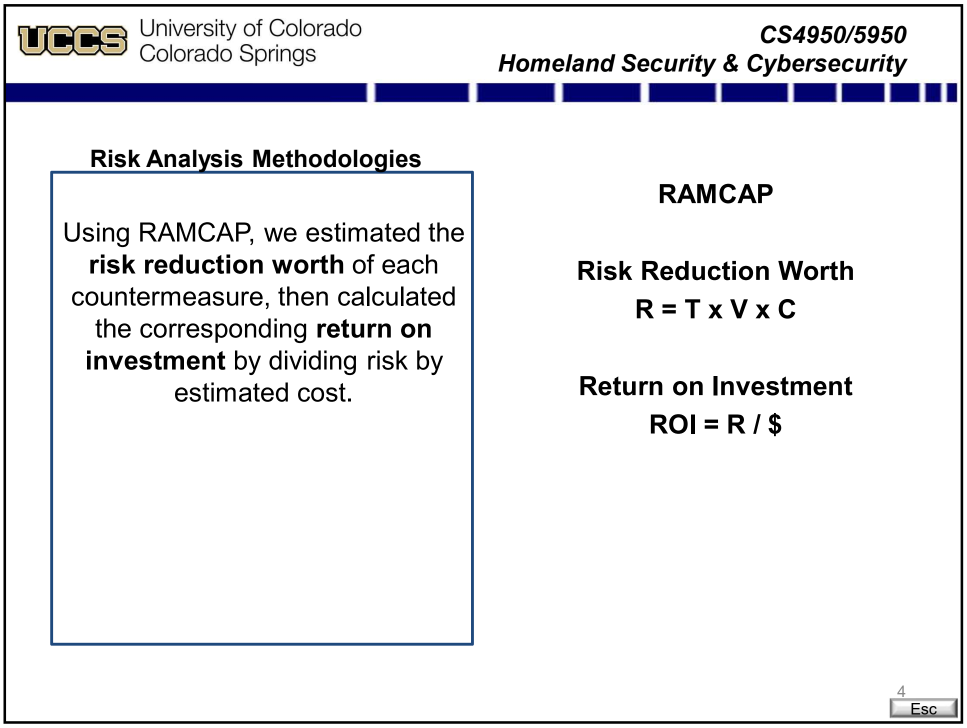

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Risk Analysis Methodologies

Using RAMCAP, we estimated the **risk reduction worth** of each countermeasure, then calculated the corresponding **return on investment** by dividing risk by estimated cost.

RAMCAP

Risk Reduction Worth
R = T x V x C

Return on Investment
ROI = R / $

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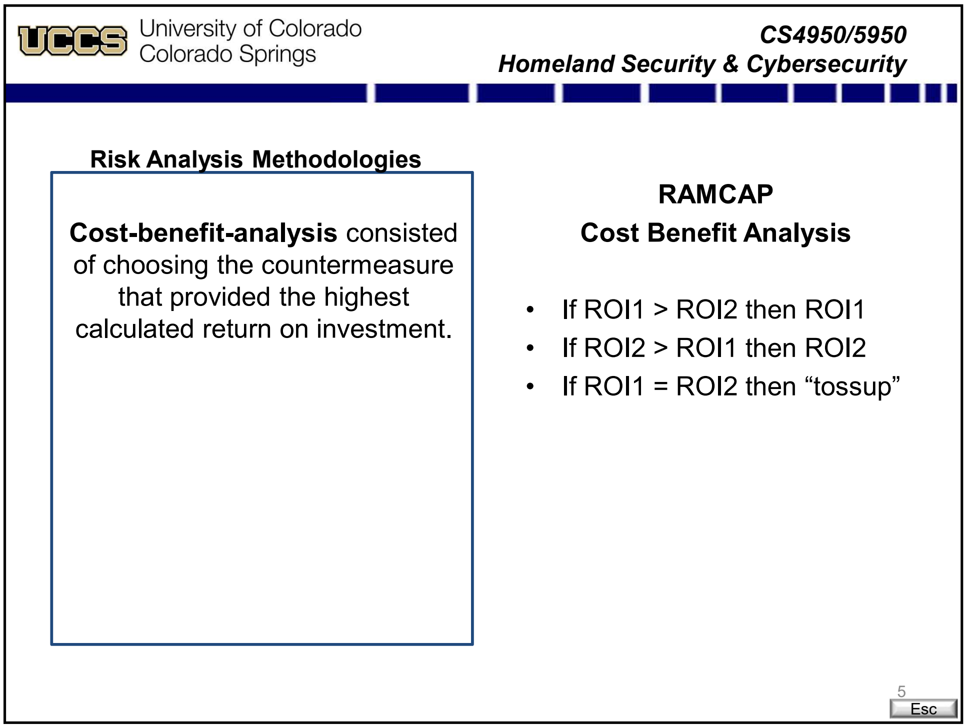

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Risk Analysis Methodologies

Cost-benefit-analysis consisted of choosing the countermeasure that provided the highest calculated return on investment.

RAMCAP
Cost Benefit Analysis

- If ROI1 > ROI2 then ROI1
- If ROI2 > ROI1 then ROI2
- If ROI1 = ROI2 then “tossup”

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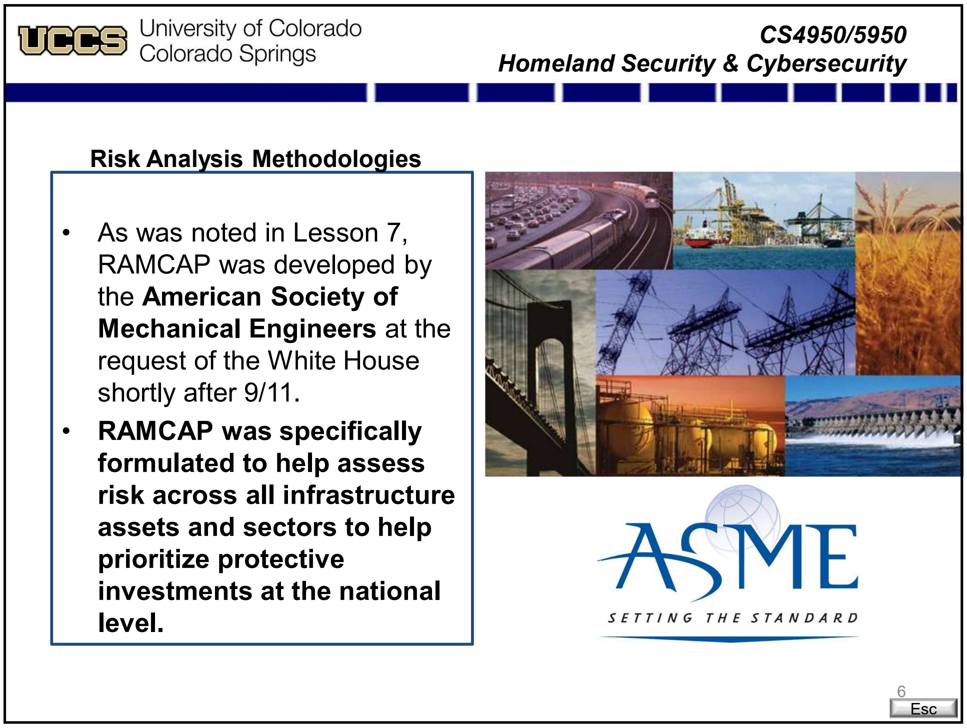

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Risk Analysis Methodologies

- As was noted in Lesson 7, RAMCAP was developed by the **American Society of Mechanical Engineers** at the request of the White House shortly after 9/11.
- **RAMCAP was specifically formulated to help assess risk across all infrastructure assets and sectors to help prioritize protective investments at the national level.**

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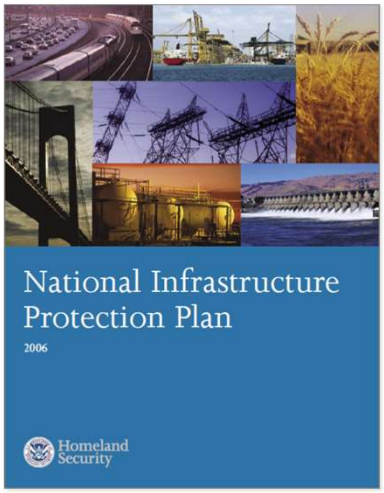
Risk Analysis Methodologies

- Unfortunately, RAMCAP fell into obscurity shortly after it was introduced in the 2006 National Infrastructure Protection Plan.
- One of the reasons RAMCAP fell into disuse was that many believe there is no “one size fits all” when it comes to risk analysis.
- Indeed, **there are an estimated 250 critical infrastructure risk methodologies,** which begs the question, **“why so many?”**



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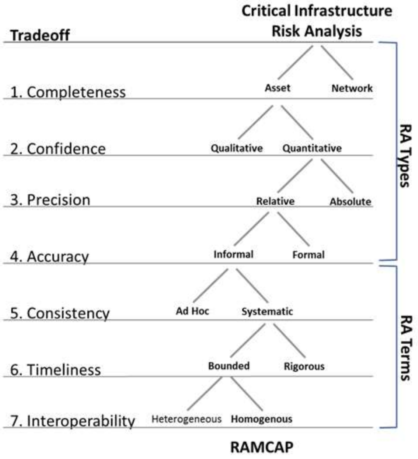
Risk Analysis Methodologies

- The answer lies in the fact that **each methodology is the result of a different set of tradeoffs.**
- RAMCAP itself is uniquely distinguished by its own set of tradeoffs.



Tradeoff

Critical Infrastructure Risk Analysis

1. Completeness — Asset / Network

2. Confidence — Qualitative / Quantitative

3. Precision — Relative / Absolute

4. Accuracy — Informal / Formal

5. Consistency — Ad Hoc / Systematic

6. Timeliness — Bounded / Rigorous

7. Interoperability — Heterogeneous / Homogenous

RAMCAP

RA Types

RA Terms

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Risk Analysis Methodologies

- It begins with the question of **completeness**: **do you analyze the network or the nodes?**
- In other words, **do you also include interdependencies** in your risk analysis?
- RAMCAP does not include interdependencies in its analysis.
- RAMCAP risk analysis focuses on the individual asset.

Tradeoff
Critical Infrastructure Risk Analysis
1. Completeness
Asset
Network

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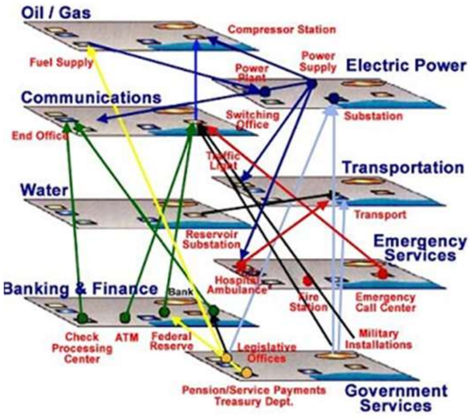
Risk Analysis Methodologies

- Many researchers justifiably argue that **risk analysis is incomplete without considering interdependencies**.
- There are at least thirty models specializing in interdependency analysis.
- Interdependency models, though, must be highly detailed to yield reasonable results.



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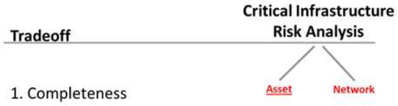
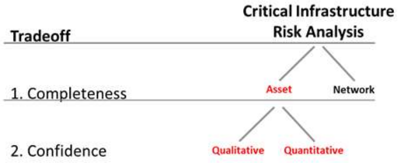
Risk Analysis Methodologies

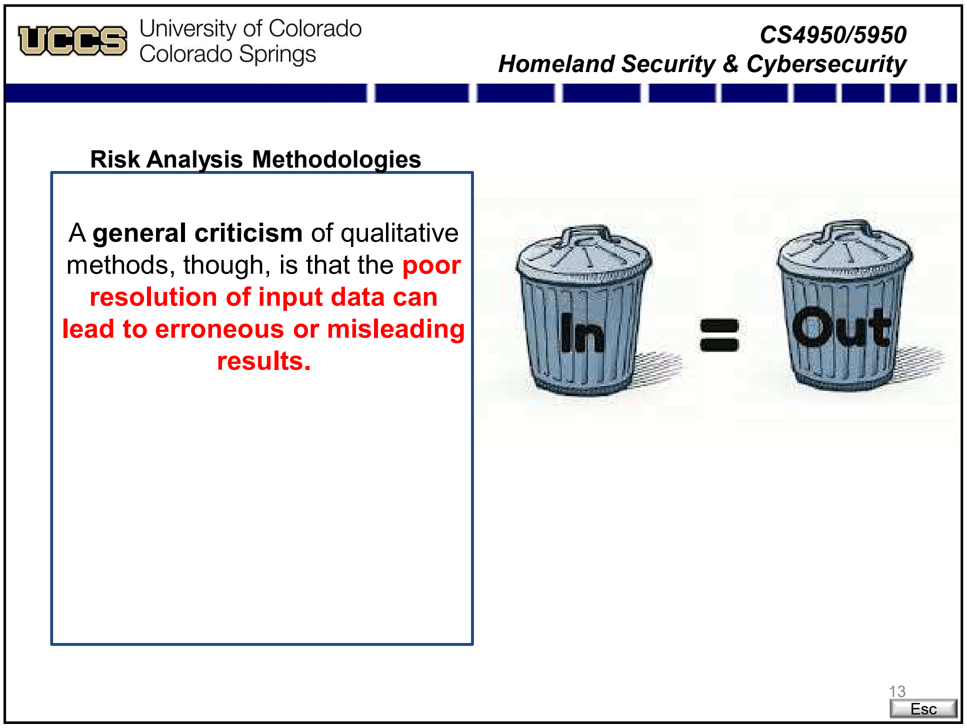
- Since assets are part of the network detail, they must be assessed at some level individually.
- **Thus it is reasonable to begin risk analysis with an asset, but understand the analysis is incomplete without including the network.**
- This was the path chosen by RAMCAP.



Risk Analysis Methodologies

- In analyzing an asset, the next tradeoff is **qualitative versus quantitative risk analysis**.
- **Qualitative risk analysis** simplifies risk assessments by reducing inputs to a manageable set of judgments.
- The Risk and Vulnerability Analysis method employed in Denmark provides one example of a qualitative approach.





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Risk Analysis Methodologies

A **general criticism** of qualitative methods, though, is that the **poor resolution of input data can lead to erroneous or misleading results.**

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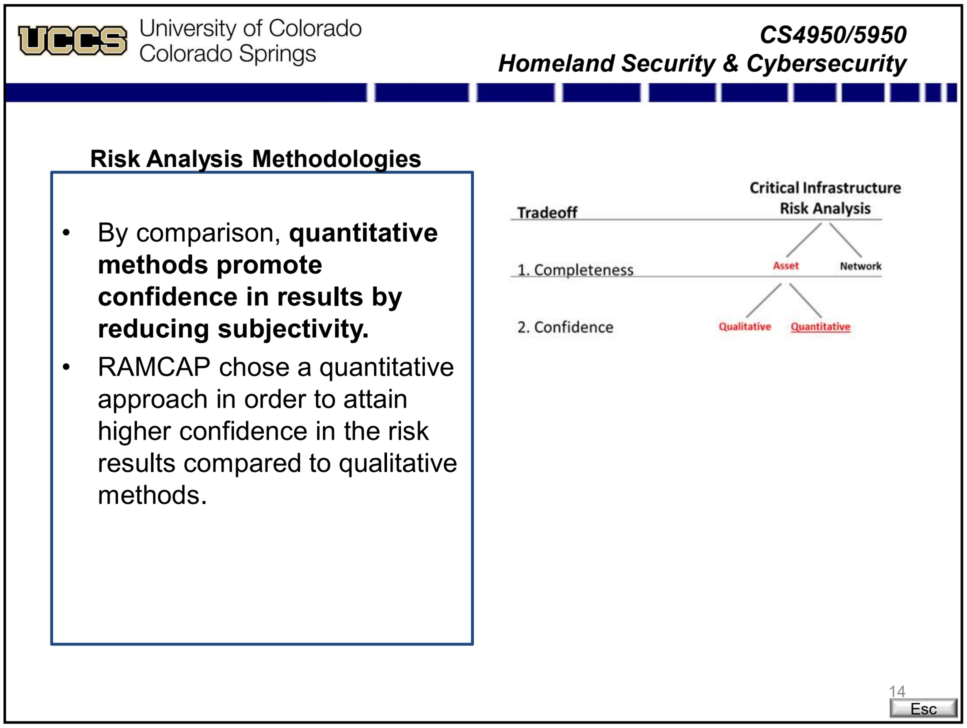

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Risk Analysis Methodologies

- By comparison, **quantitative methods promote confidence in results by reducing subjectivity.**
- RAMCAP chose a quantitative approach in order to attain higher confidence in the risk results compared to qualitative methods.

Tradeoff

Critical Infrastructure Risk Analysis

1. Completeness — Asset, Network

2. Confidence — Qualitative, Quantitative

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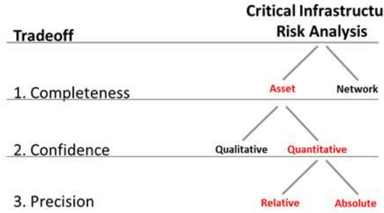
Risk Analysis Methodologies

- The quantitative approach, however, is tempered by **precision**.
- Various methods are advocated to achieve a high level of precision in estimating risk, including **Bayesian Networks, Conditional Linear Gaussian Networks, Stochastic Models** and other formal quantitative methods with **proven records of performance in diverse fields of engineering, finance, healthcare, and meteorology.**



Critical Infrastructure Risk Analysis

Tradeoff

1. Completeness — Asset, Network

2. Confidence — Qualitative, Quantitative

3. Precision — Relative, Absolute

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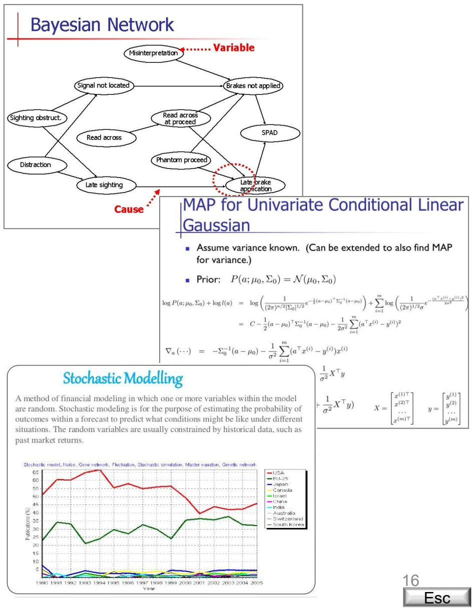
Risk Analysis Methodologies

- **What trips up these methods with critical infrastructure** is the **lack of data for statistical analysis** of manmade catastrophic incidents.
- RAMCAP encourages precision at every step in the risk analysis process, but accepts that in the absence of complete data, **precision is an unattainable goal.**



Bayesian Network

MAP for Univariate Conditional Linear Gaussian

- Assume variance known. (Can be extended to also find MAP for variance.)
- Prior: $P(a;\mu_0,\Sigma_0)=\mathcal{N}(\mu_0,\Sigma_0)$

$$\log P(a;\mu_0,\Sigma_0)+\log l(a) = \log\left(\frac{1}{(2\pi)^{n/2}|\Sigma_0|^{1/2}}e^{-\frac{1}{2}(a-\mu_0)^\top\Sigma_0^{-1}(a-\mu_0)}\right)+\sum_{i=1}^{m}\log\left(\frac{1}{(2\pi)^{1/2}\sigma}e^{-\frac{(a^\top x^{(i)}-y^{(i)})^2}{2\sigma^2}}\right)$$

$$= C-\frac{1}{2}(a-\mu_0)^\top\Sigma_0^{-1}(a-\mu_0)-\frac{1}{2\sigma^2}\sum_{i=1}^{m}(a^\top x^{(i)}-y^{(i)})^2$$

$$\nabla_a(\cdots) = -\Sigma_0^{-1}(a-\mu_0)-\frac{1}{\sigma^2}\sum_{i=1}^{m}(a^\top x^{(i)}-y^{(i)})x^{(i)}$$

$$\frac{1}{\sigma^2}X^\top y$$

$$+\frac{1}{\sigma^2}X^\top y) \qquad X=\begin{bmatrix}x^{(1)\top}\\x^{(2)\top}\\\dots\\x^{(m)\top}\end{bmatrix} \qquad y=\begin{bmatrix}y^{(1)}\\y^{(2)}\\\dots\\y^{(m)}\end{bmatrix}$$

Stochastic Modelling

A method of financial modeling in which one or more variables within the model are random. Stochastic modeling is for the purpose of estimating the probability of outcomes within a forecast to predict what conditions might be like under different situations. The random variables are usually constrained by historical data, such as past market returns.

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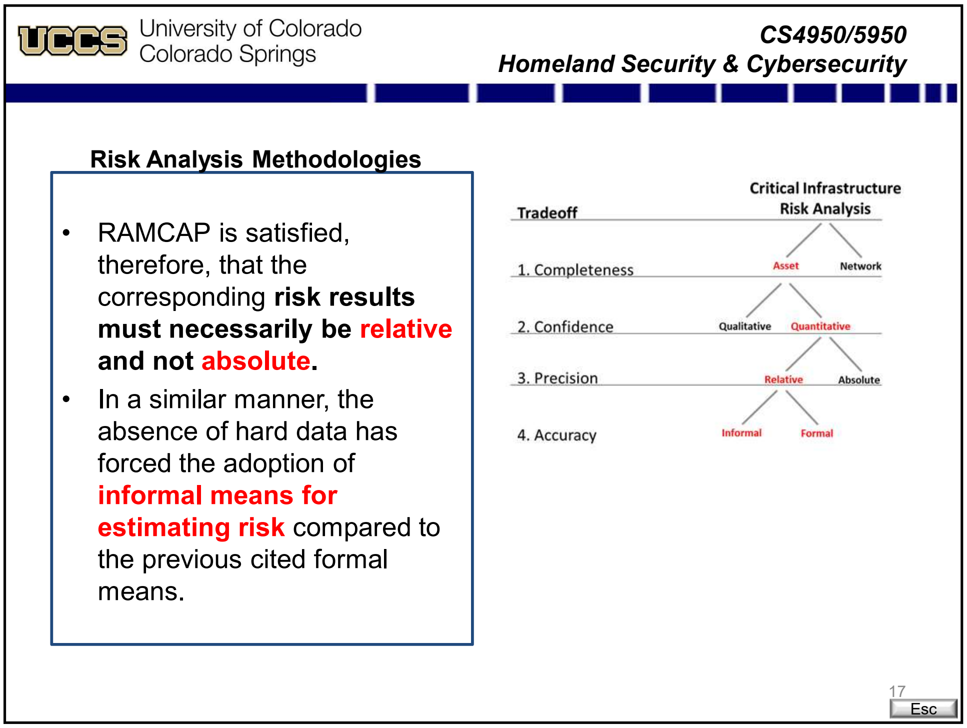

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Risk Analysis Methodologies

- RAMCAP is satisfied, therefore, that the corresponding **risk results must necessarily be relative and not absolute.**
- In a similar manner, the absence of hard data has forced the adoption of **informal means for estimating risk** compared to the previous cited formal means.

Tradeoff — Critical Infrastructure Risk Analysis

1. Completeness — Asset / Network
2. Confidence — Qualitative / Quantitative
3. Precision — Relative / Absolute
4. Accuracy — Informal / Formal

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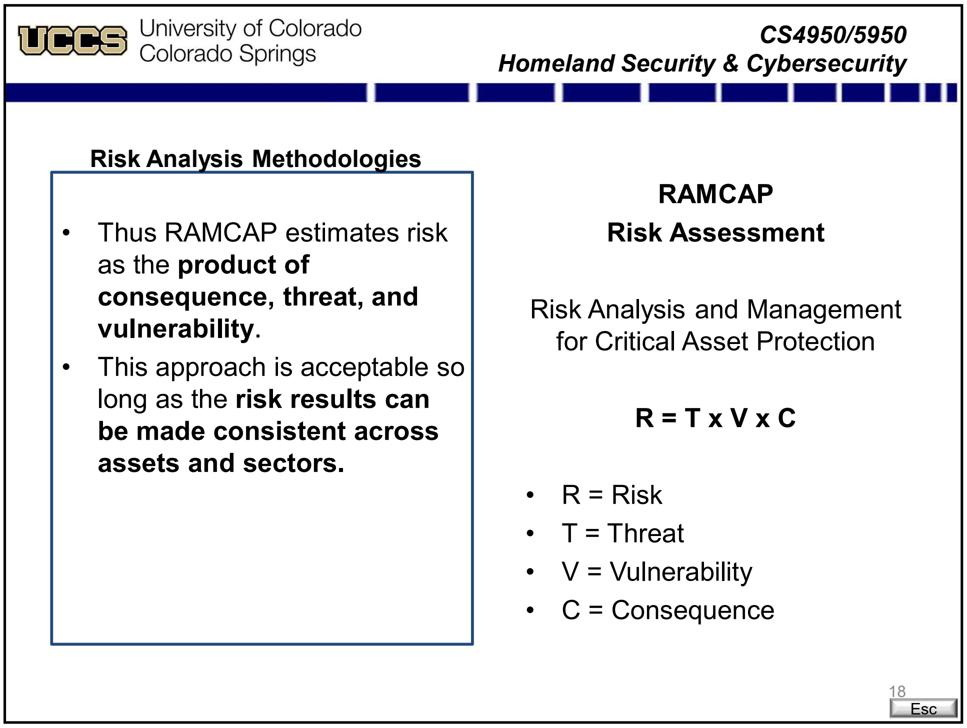

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Risk Analysis Methodologies

- Thus RAMCAP estimates risk as the **product of consequence, threat, and vulnerability**.
- This approach is acceptable so long as the **risk results can be made consistent across assets and sectors.**

RAMCAP
Risk Assessment

Risk Analysis and Management for Critical Asset Protection

R = T x V x C

- R = Risk
- T = Threat
- V = Vulnerability
- C = Consequence

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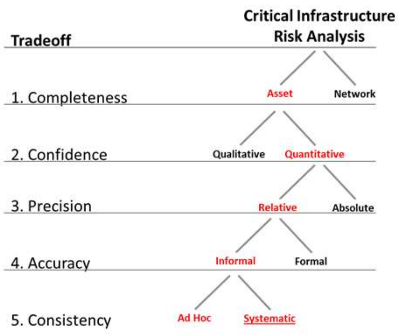
Risk Analysis Methodologies

- RAMCAP achieves consistency by systematically applying the same risk formulation across assets and sectors.
- **Consistency** can be further improved by applying **rigorous methods for estimating terms** in the RAMCAP formulation.



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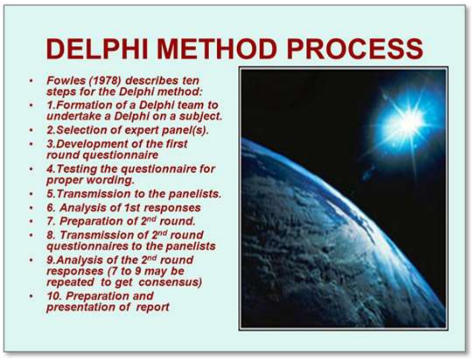
Risk Analysis Methodologies

- **Rigorous methods** for estimating consequence, threat, and vulnerability values **encompass various means of elicitation and modeling.**
- The **Delphi Method** is perhaps the best known rigorous system among elicitation methods.



DELPHI METHOD PROCESS

- *Fowles (1978) describes ten steps for the Delphi method:*
- *1.Formation of a Delphi team to undertake a Delphi on a subject.*
- *2.Selection of expert panel(s).*
- *3.Development of the first round questionnaire*
- *4.Testing the questionnaire for proper wording.*
- *5.Transmission to the panelists.*
- *6. Analysis of 1st responses*
- *7. Preparation of 2nd round.*
- *8. Transmission of 2nd round questionnaires to the panelists*
- *9.Analysis of the 2nd round responses (7 to 9 may be repeated to get consensus)*
- *10. Preparation and presentation of report*

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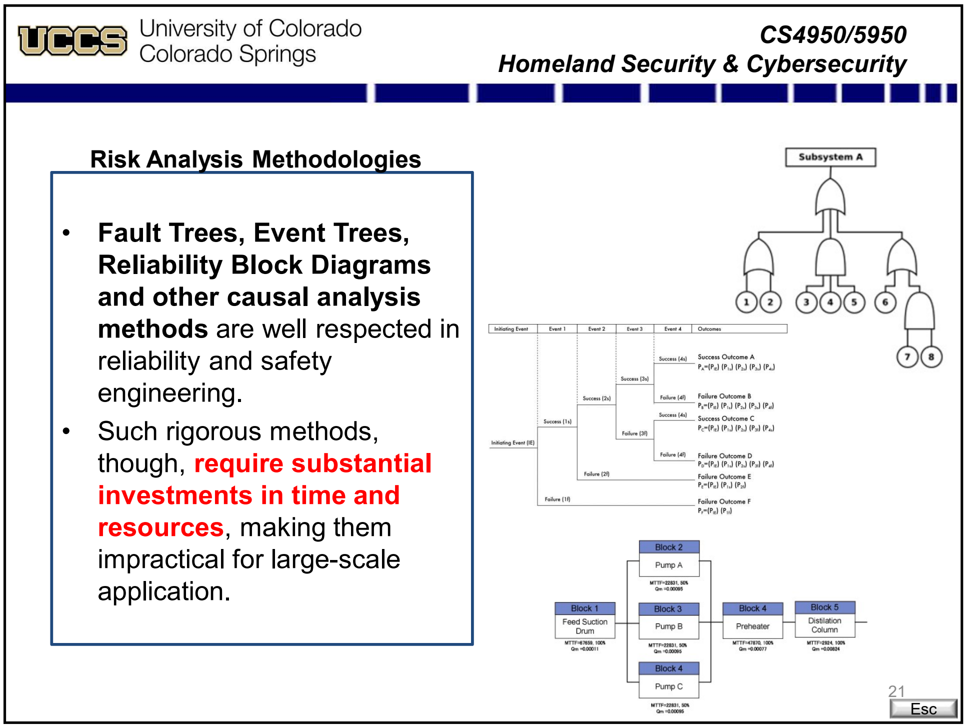

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Risk Analysis Methodologies

- **Fault Trees, Event Trees, Reliability Block Diagrams and other causal analysis methods** are well respected in reliability and safety engineering.
- Such rigorous methods, though, **require substantial investments in time and resources**, making them impractical for large-scale application.

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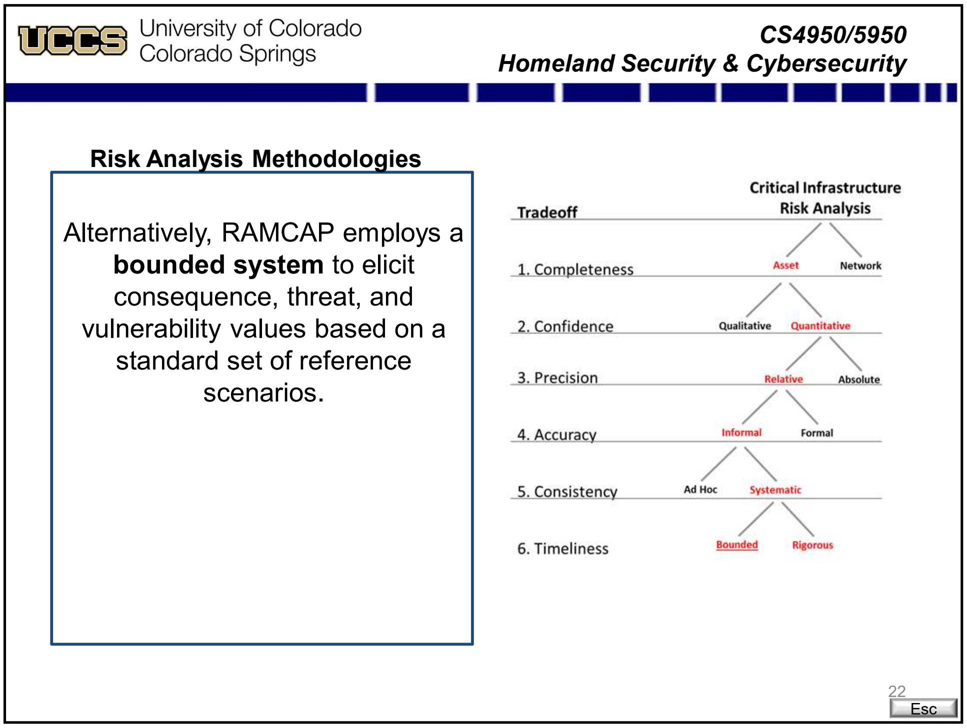

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Risk Analysis Methodologies

Alternatively, RAMCAP employs a **bounded system** to elicit consequence, threat, and vulnerability values based on a standard set of reference scenarios.

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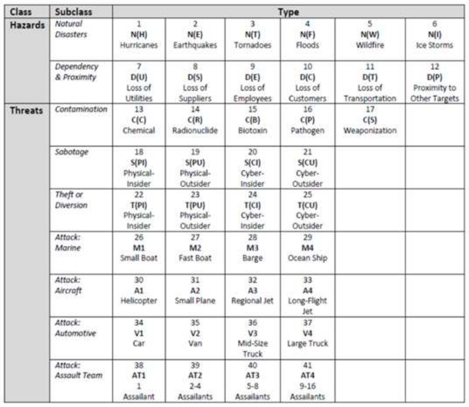
Risk Analysis Methodologies

- These scenarios currently include **forty-one different natural and manmade hazards**.
- Using these same reference scenarios also **promotes interoperability** by facilitating comparison of RAMCAP risk results across infrastructure assets and sectors.



Class	Subclass	Type					
Hazards	*Natural Disasters*	1 **N(H)** Hurricanes	2 **N(E)** Earthquakes	3 **N(T)** Tornadoes	4 **N(F)** Floods	5 **N(W)** Wildfire	6 **N(I)** Ice Storms
	Dependency & Proximity	7 **D(U)** Loss of Utilities	8 **D(S)** Loss of Suppliers	9 **D(E)** Loss of Employees	10 **D(C)** Loss of Customers	11 **D(T)** Loss of Transportation	12 **D(P)** Proximity to Other Targets
Threats	*Contamination*	13 **C(C)** Chemical	14 **C(R)** Radionuclide	15 **C(B)** Biotoxin	16 **C(P)** Pathogen	17 **C(S)** Weaponization	
	Sabotage	18 **S(PI)** Physical-Insider	19 **S(PU)** Physical-Outsider	20 **S(CI)** Cyber-Insider	21 **S(CU)** Cyber-Outsider		
	Theft or Diversion	22 **T(PI)** Physical-Insider	23 **T(PU)** Physical-Outsider	24 **T(CI)** Cyber-Insider	25 **T(CU)** Cyber-Outsider		
	Attack: Marine	26 **M1** Small Boat	27 **M2** Fast Boat	28 **M3** Barge	29 **M4** Ocean Ship		
	Attack: Aircraft	30 **A1** Helicopter	31 **A2** Small Plane	32 **A3** Regional Jet	33 **A4** Long-Flight Jet		
	Attack: Automotive	34 **V1** Car	35 **V2** Van	36 **V3** Mid-Size Truck	37 **V4** Large Truck		
	Attack: Assault Team	38 **AT1** 1 Assailant	39 **AT2** 2-4 Assailants	40 **AT3** 5-8 Assailants	41 **AT4** 9-16 Assailants		

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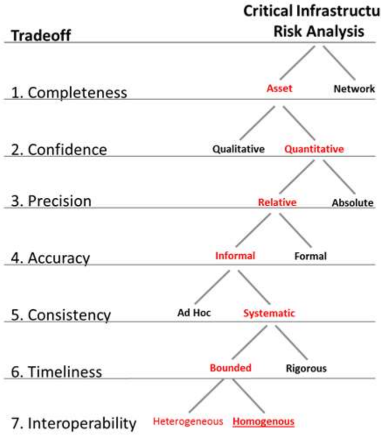
Risk Analysis Methodologies

This ability to compare risk results "apples-to-apples" across assets and sectors perfectly suited the purpose for which **RAMCAP was designed, specifically to make strategic decisions about national investments in critical infrastructure protection.**



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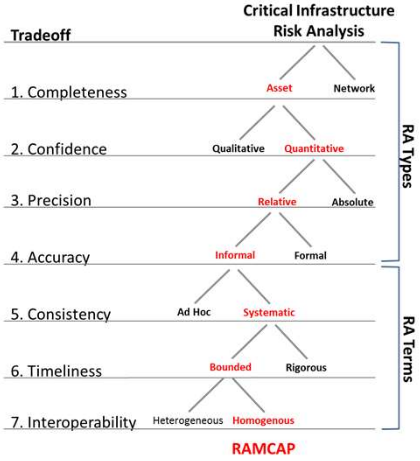
Risk Analysis Methodologies

The point of this lesson with respect to cybersecurity is that infrastructure **owners and operators may undergo a similar exercise to develop their own risk analysis methodology that's tailored to their own unique set of circumstance.**



Critical Infrastructure Risk Analysis

Tradeoff

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7. Interoperability — Heterogeneous / Homogenous

RA Types

RA Terms

RAMCAP

Conclusion

Questions?