

Criteria for Comparative Evaluations of Treaty Verification Systems

Angela Waterworth¹, **Jay Brotz**², Jacob Benz¹, Matthew McDougall¹, Danielle Hauck³, Daniel Krementz⁴, Gary Cockrell⁵, George Weeks⁶

17 July 2017

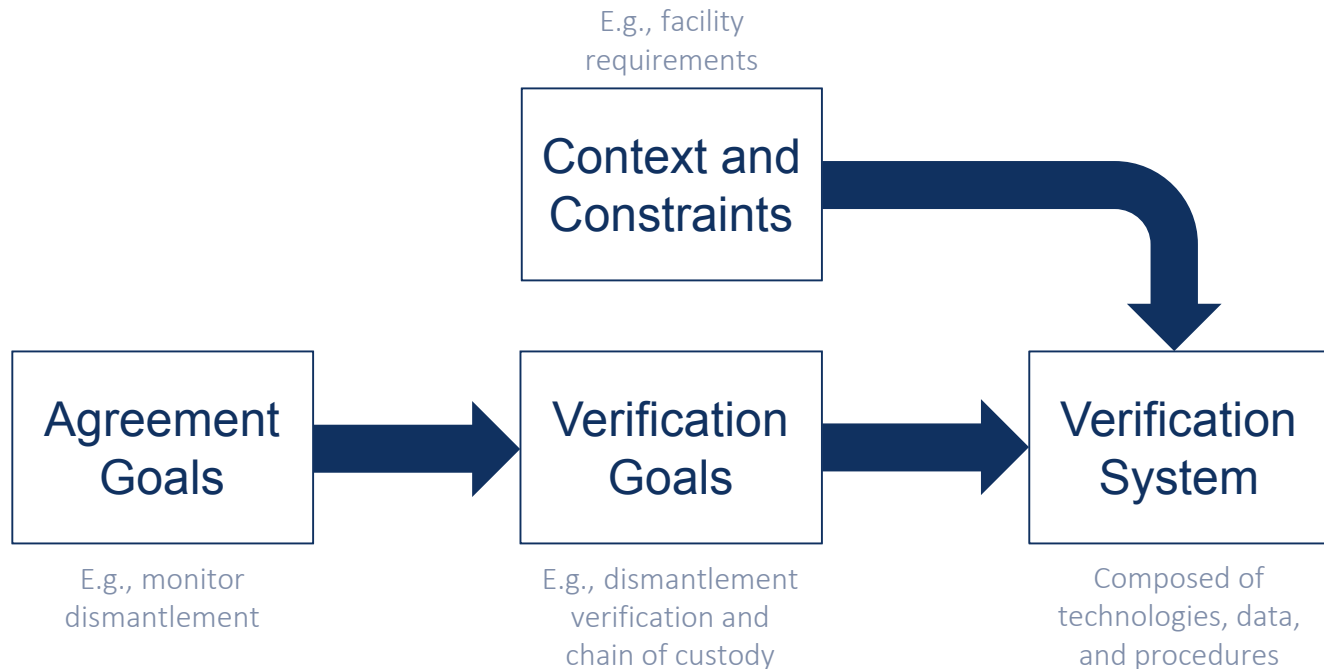
INMM 58th Annual Meeting, Indian Wells, CA

¹Pacific Northwest National Laboratory, ²Sandia National Laboratories, ³Los Alamos National Laboratory, ⁴Savannah River National Laboratory, ⁵Pantex Plant, ⁶Crimson Sky Consulting



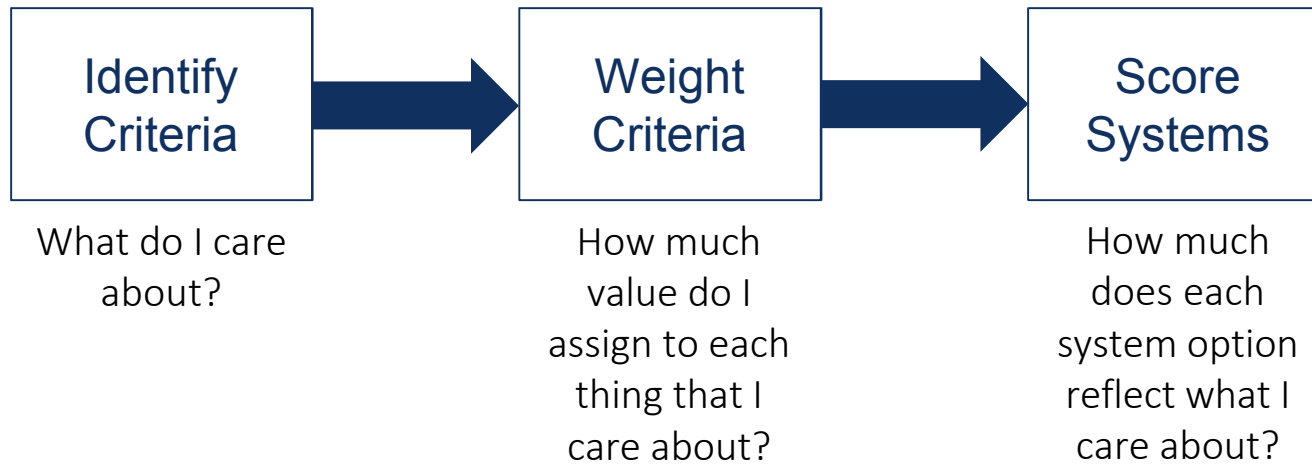
The Problem

- Negotiators and R&D policymakers need to be able to compare among competing designs for verification systems



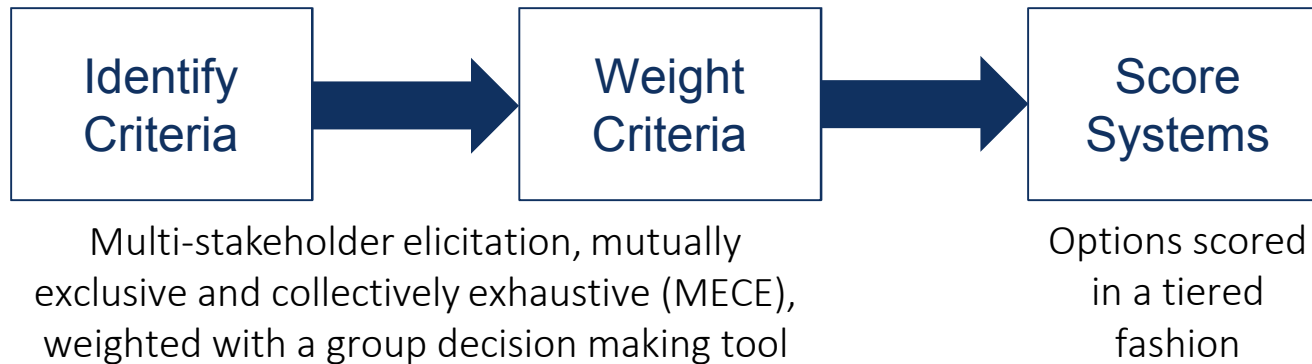
- Options analysis for treaty verification systems has challenges
 - How do we identify requirements?
 - How do we measure performance?
 - Are we satisfied with expert opinion, or is there a better way?
 - How do we compare systems designed in a research effort?

Comparing System Options



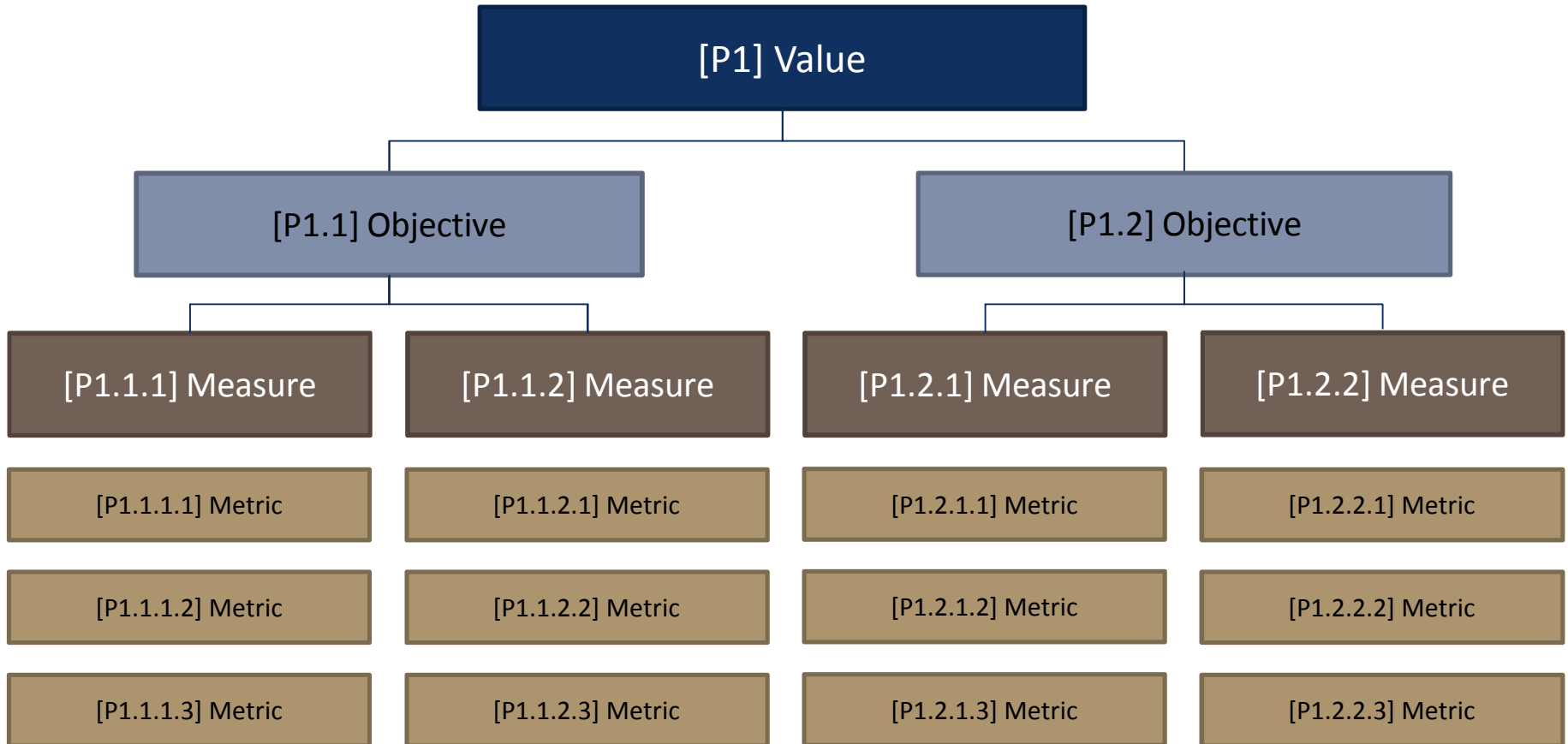
- For many systems engineering problems, this looks like:
 - Identify measurable requirements
 - Flow down performance contributions to atomic requirements
 - Measure performance and calculate top-level metrics
- But, this requires precise, measurable requirements

Comparing Verification System Options

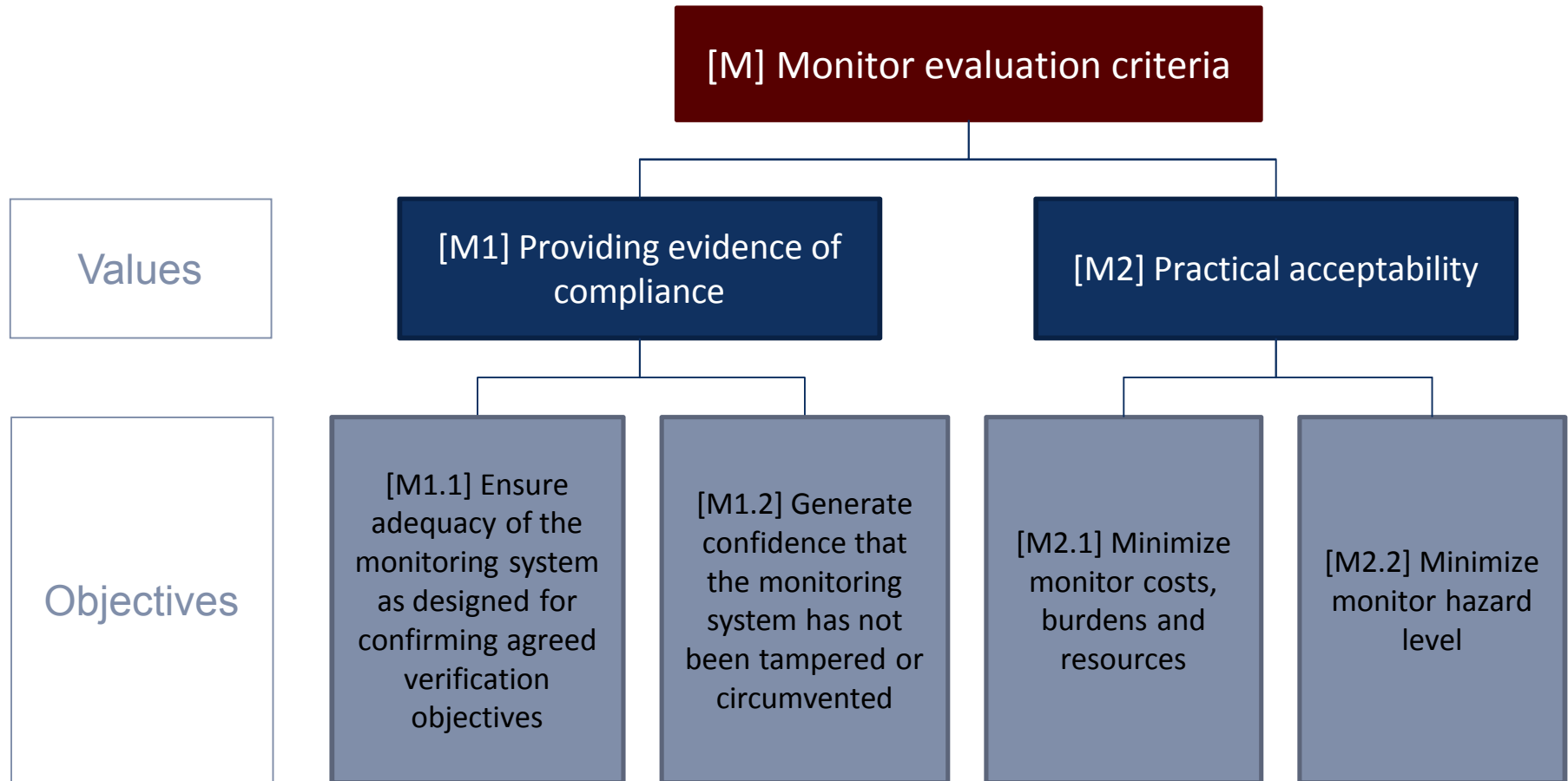


- We have identified a process to elicit mutually exclusive and collective exhaustive (MECE) criteria from all relevant stakeholders
- The criteria can be weighted and the options scored with a group decision making tool (such as the Analytic Hierarchy Process)
- Two sets of criteria – for the **Host** and for the **Monitor** – are appropriate for on-site verification systems
- Criteria are identified in two categories: benefits and costs

Criteria Tree



Example: Monitor Criteria (top level)



Example: Monitor Criteria (benefits)

Measures

[M1.1.1] Completeness of coverage of the monitoring system data to support confirmation of verification objectives

[M1.1.2] Accuracy of the monitoring system as designed

[M1.2.1] Ability to detect and prevent useful tampering of the monitoring system

[M1.2.2] Ability to detect and prevent the monitoring system from being circumvented

[M1.1.1.1] Measure of coverage of treaty obligations

[M1.1.2.1] Measure of accuracy of the Monitor data provided by the monitor system as designed

[M1.2.1.1] Probability of detecting useful tampering of the monitoring system

[M1.2.2.1] Probability of detecting circumvention of the monitoring system

[M1.1.1.2] Measure of usefulness of the data for confirming verification objectives

[M1.2.1.2] Measure of the unmitigated vulnerability of the monitoring system to tampering

[M1.2.2.2] Measure of the unmitigated vulnerability of the monitoring system to circumvention

[M1.1.1.3] Measure of operational availability of the monitoring system as designed

Metrics

Example: Monitor Criteria (costs)

Measures

[M2.1.1] Costs, burdens, and resources required for preparing and implementing the regime as designed

[M2.1.2] Costs, burdens, and resources associated with the Monitor gaining and maintaining confidence that the monitoring system has not been tampered

[M2.2.1] Monitor personnel safety

Metrics

[M2.1.1.1] Cost of monitoring equipment

[M2.1.1.2] Cost of Monitor safety

[M2.1.1.3] Cost of setting up the regime

[M2.1.1.4] Time required for setting up the regime

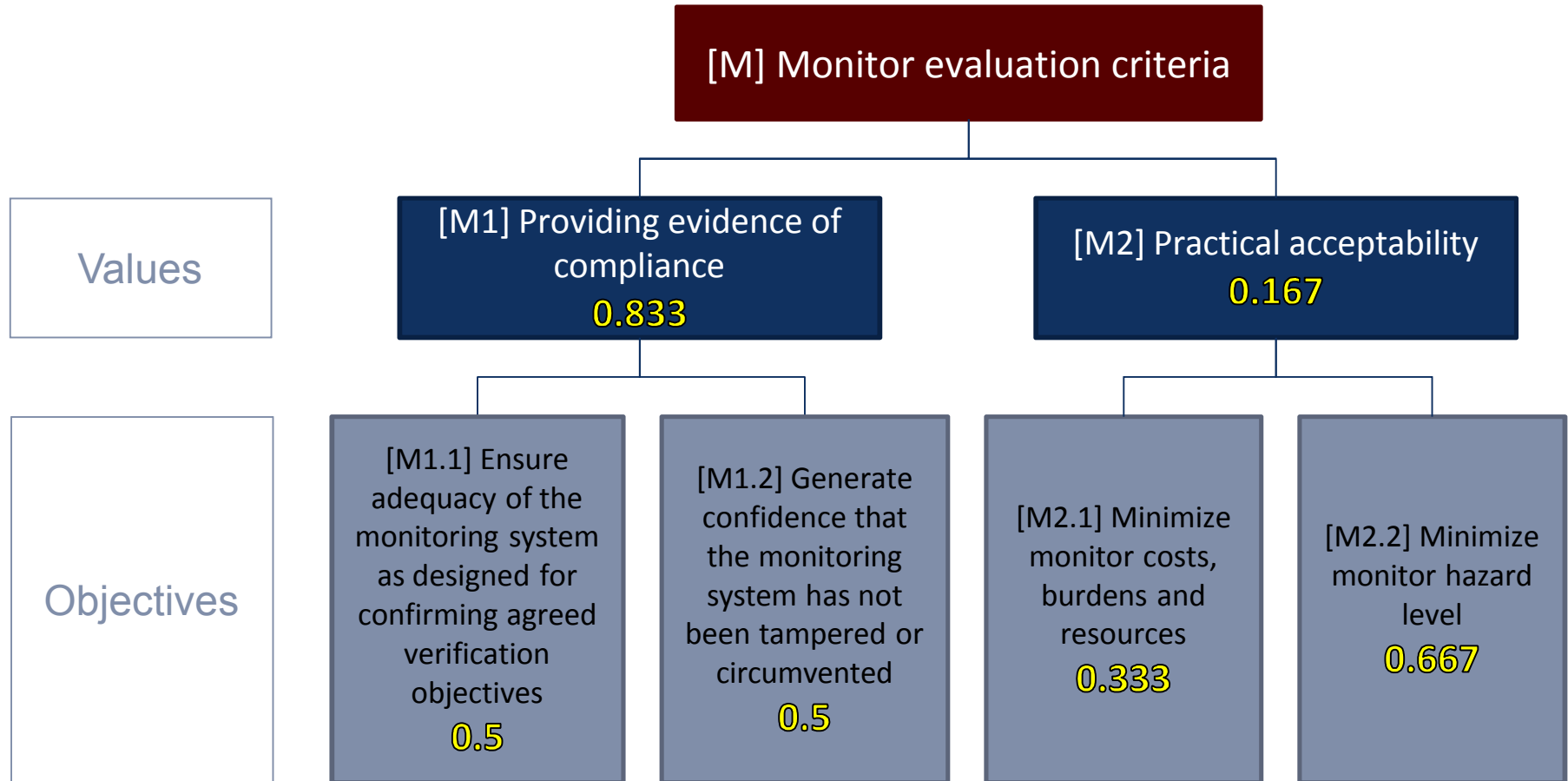
[M2.1.1.5] Inspection cost

[M2.1.1.6] Cost of disposal and removal

[M2.1.2.1] Cost of gaining and maintaining confidence that the monitoring system has not been tampered to alter compliance confirmation

[M2.2.1.1] Assessment of safety risk

Weighting Monitor Criteria (top level)



Weighting Monitor Criteria (benefits)

Measures

[M1.1.1] Completeness of coverage of the monitoring system data to support confirmation of verification objectives
0.8

[M1.1.2] Accuracy of the monitoring system as designed
0.2

[M1.2.1] Ability to detect and prevent useful tampering of the monitoring system
0.5

[M1.2.2] Ability to detect and prevent the monitoring system from being circumvented
0.5

Metrics

[M1.1.1.1] Measure of coverage of treaty obligations
0.582 [19.4%]

[M1.1.1.2] Measure of usefulness of the data for confirming verification objectives
0.11 [3.6%]

[M1.1.1.3] Measure of operational availability of the monitoring system as designed
0.31 [10.3%]

[M1.1.2.1] Measure of accuracy of the Monitor data provided by the monitor system as designed
[8.3%]

[M1.2.1.1] Probability of detecting useful tampering of the monitoring system
0.25 [5.2%]

[M1.2.1.2] Measure of the unmitigated vulnerability of the monitoring system to tampering
0.75 [15.6%]

[M1.2.2.1] Probability of detecting circumvention of the monitoring system
0.25 [5.2%]

[M1.2.2.2] Measure of the unmitigated vulnerability of the monitoring system to circumvention
0.75 [15.6%]

Weighting Monitor Criteria (costs)

Measures

[M2.1.1] Costs, burdens, and resources required for preparing and implementing the regime as designed

[M2.1.2] Costs, burdens, and resources associated with the Monitor gaining and maintaining confidence that the monitoring system has not been tampered

[M2.2.1] Monitor personnel safety

[M2.1.1.1] Cost of monitoring equipment

[M2.1.1.2] Cost of Monitor safety

[M2.1.1.3] Cost of setting up the regime

[M2.1.1.4] Time required for setting up the regime

[M2.1.1.5] Inspection cost

[M2.1.1.6] Cost of disposal and removal

[M2.1.2.1] Cost of gaining and maintaining confidence that the monitoring system has not been tampered to alter compliance confirmation

[M2.2.1.1] Assessment of safety risk
[11.1%]

Metrics

[5.6%]

Scoring a System Option

Metric	Global Weight	Option 1	Option 2	Option 3
[M1.1.1.1] Measure of coverage of treaty obligations	19.4%	33	84	53
[M1.1.1.2] Measure of usefulness of the data for confirming verification objectives	3.6%	15	36	64
[M1.1.1.3] Measure of operational availability of the monitoring system as designed	10.3%	97	42	97
[M1.1.2.1] Measure of accuracy of the Monitor data provided by the monitor system as designed	8.3%	93	11	23
[M1.2.1.1] Probability of detecting useful tampering of the monitoring system	5.2%	42	77	29
[M1.2.1.2] Measure of the unmitigated vulnerability of the monitoring system to tampering	15.6%	22	15	25
[M1.2.2.1] Probability of detecting circumvention of the monitoring system	5.2%	47	77	75
[M1.2.2.2] Measure of the unmitigated vulnerability of the monitoring system to circumvention	15.6%	10	64	29
[M2.1] Minimize monitor costs, burdens and resources	5.6%	55	34	41
[M2.2.1.1] Assessment of safety risk	11.1%	6	12	80
Total (option scores normalized)	100%	.284	.346	.370

Conclusion

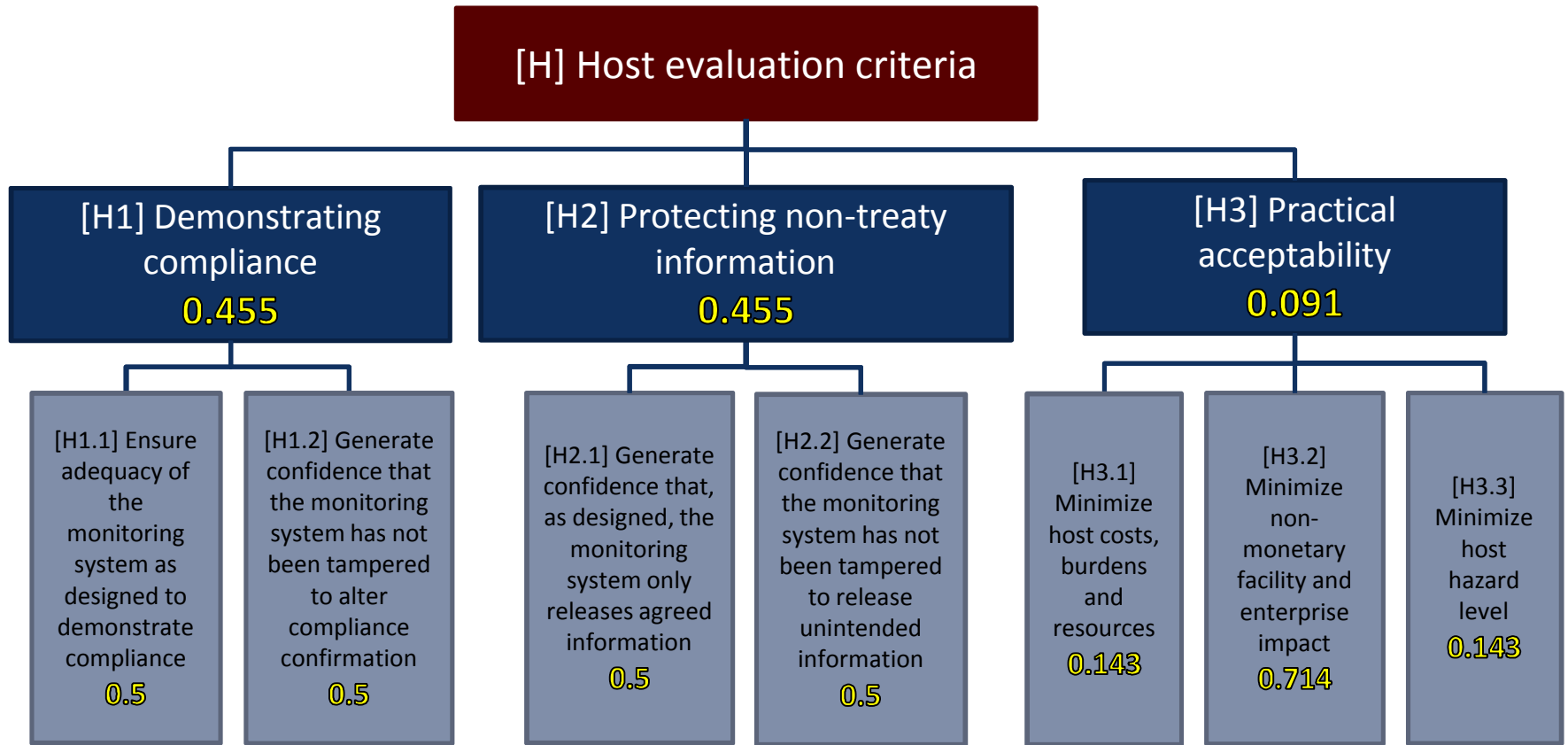
- We have presented a process for *comparative evaluation* of treaty verification system options using expert opinion in a systematic way
 - Objective data can be used where it exists, and subjective data (i.e., expert judgement) can be used to fill in the gaps
- Key lessons:
 - The criteria tree, weightings, and options scores will change for different stakeholders (only examples are shown in these slides)
 - Displaying the criteria tree, weightings, and all calculations transparently will support the process (and revisions that need to be made)
- Next steps:
 - Validation with a relevant regime and set of verification systems, conducted with relevant stakeholders

- The authors would like to acknowledge the generous support of the NNSA Office of Nuclear Verification for this work.

Questions?

Backup Slides

Example: Host Criteria (top level)



Example: Host Criteria (benefits)

Measures

[H1.1.1] Completeness of coverage of the monitoring system data to support compliance demonstration

0.167

[H1.1.2] Accuracy of the monitoring systems as designed

0.833

[H1.2.1] Ability to detect and prevent useful tampering of the monitoring system

Metrics

[H1.1.1.1] Measure of coverage of treaty obligations

0.1 [0.4%]

[H1.1.2.1] Accuracy of the data provided by the monitoring system as designed

[18.9%]

[H1.2.1.1] Probability of detecting useful tampering of the monitoring system to alter compliance confirmation

0.667 [15.2%]

[H1.1.1.2] Measure of usefulness of the data for demonstrating compliance

0.226 [0.9%]

[H1.2.1.2] Measure of the unmitigated vulnerability of the monitoring system to tampering to alter compliance confirmation

0.333 [7.6%]

[H1.1.1.3] Measure of operational availability of the system(s) used by the Host (i.e. uptime)

0.674 [2.6%]

Example: Host Criteria (benefits)

Measures

[H2.1.1] Confidence that, as designed, the monitoring system only releases intended information

0.8

[H2.1.2] Confidence that, as designed, the monitoring system only releases agreed data

0.2

[H2.2.1] Ability to detect and prevent useful tampering of the monitoring system to release unagreed data

Metrics

[H2.1.1.1] Measure of confidence that unintended information cannot be derived from the agreed data

[18.2%]

[H2.1.2.1] Measure of confidence that, as designed, the monitor only receives agreed data from the monitoring system

[4.5%]

[H2.2.1.1] Probability of detecting useful tampering of the monitoring system to release unagreed data

0.667 [15.2%]

[H2.2.1.2] Measure of the unmitigated vulnerability of the monitoring system to tampering to release unagreed data

0.333 [7.6%]

Example: Host Criteria (costs)

Measures

[H3.1.1] Costs, burdens, and resources required for preparing and implementing the regime as designed

[H3.1.2] Costs, burdens, and resources associated with the Host gaining and maintaining confidence that the monitoring system has not been tampered or subverted

[H3.2.1] Facility impact
0.125

[H3.2.2] Enterprise impact
0.875

[H3.3.1] Host facility and operations safety

[H3.1.1.1] Cost of monitoring equipment

[H3.1.1.2] Cost of Monitor safety

[H3.1.1.3] Cost of Host security

[H3.1.1.4] Cost of setting up the regime

[H3.1.1.5] Time required for setting up the regime

[H3.1.1.6] Inspection cost

[H3.1.1.7] Cost of disposal and removal

[H3.1.2.1] Cost of Host gaining and maintaining confidence that the monitoring system has not been tampered to alter compliance confirmation

[H3.1.2.2] Cost of Host gaining and maintaining confidence that the monitoring system has not been subverted to release unagreed data

[H3.2.1.1] Non-monetary measures of the impacts to the facility
[0.8%]

[H3.2.2.1] Non-monetary measures for the impacts to the enterprise
[5.7%]

[H3.3.1.1] Safety risk assessment to Host facility and personnel
[1.3%]

Metrics

Weights of Monitor Criteria

Global Weight

- [M1.1.1.1] Measure of coverage of treaty obligations
- [M1.1.1.2] Measure of usefulness of the data for confirming verification objectives
- [M1.1.1.3] Measure of operational availability of the monitoring system as designed
- [M1.1.2.1] Measure of accuracy of the Monitor data provided by the monitor system as designed
- [M1.2.1.1] Probability of detecting useful tampering of the monitoring system
- [M1.2.1.2] Measure of the unmitigated vulnerability of the monitoring system to tampering
- [M1.2.2.1] Probability of detecting circumvention of the monitoring system
- [M1.2.2.2] Measure of the unmitigated vulnerability of the monitoring system to circumvention

