CTD WS 612

Establishing Availability Requirements Using Characteristics Factors and Expert Opinion

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Background

- System design engineers must translate permitted overall facility downtime into detailed design specifications for systems that make up the facility
- Availability criteria for individual systems is often established using a "bottom-up" approach when detailed design is known.
- When detailed design is not known, a "top-down" approach is intuitively more satisfying

"Top-Down" Approach to Availability Apportionment

- An overall facility requirement is divided first among facility systems, then among subsystems
- The requirement is distributed proportionately among facility systems, based on each systems capability for meeting the design objective
- Optimizations such as this result in lower facility costs

Example: Contractor Selection

	Characteristic			
	Cost	Technical Approach	Experience	Score
Company #1	– – –	– – –	– – –	– – –
Company #2	– – –	– – –	– – –	– – –
Company #3	– – –	– – –	– – –	– – –
	100	100	100	

Weighting Factors For Characteristics

- Characteristics that influence equipment reliability and maintainability must be established to allocate facility availability
- Reliability
  - system complexity
  - design immaturity
  - stressful operating environment
- Maintainability
  - fault detection and diagnosis time
  - preparation time to conduct repair
  - fault correction time
  - restart time

Paired Comparison Method of Determining Weighting Factors

- Analytical hierarchy process is used to produce weighting factors for each alternative
- A paired comparison procedure is used
- A principal technical expert is chosen to represent each system. A structural interview is conducted for each expert individually. Team aggregation and final adjustments made at the conclusion

Example Application

- Spallation Neutron Source Project in Oak Ridge, TN
- Cost ~$1.3 billion, operational in year 2005
- Five partner national laboratories
- Overall facility availability requirement, 90%

Equations

$$\frac{R_i}{\theta_i} = \left[\frac{y_i z_i}{\sum_{i=1}^{n} y_i z_i}\right]\left(\frac{1}{A_s} - 1\right)$$

$$\frac{1}{A_i} = \frac{1}{1 + (R_i/\theta_i)}$$

where

A_s = overall facility availability requirement

A_i = apportioned availability for the i^{th} system

θ_i = mean time between failure for the i^{th} system

R_i = mean time to repair for the i^{th} system

z_i = mean time between failure weighting factor for i^{th} system

y_i = mean time to repair weighting factor for i^{th} system

Apportioned SNS Availability

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W.B.S.		Availability Requirement	Downtime per 6 week run (h)
1.3	Front End Systems	99.5%	5.0
1.4	LINAC	97.5%	25.6
1.5	Ring and Transfer Line	96.9%	32.0
1.6	Target	96.3%	38.4
1.7	Experiment Systems	100%	0
1.8	Conventional Facilities	99.7%	3.0
1.9	Control Systems	99.7%	3.0

Overall 90%

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Compare Mean-Time-Between-Failure Criteria: Example

1	COMPLXTY	9	8	7	6	5	④	3	2	**1**	2	3	4	5	6	7	8	9	IMMATURE
2	COMPLXTY	9	8	7	6	5	4	3	②	**1**	2	3	4	5	6	7	8	9	STRESS-E
3	IMMATURE	9	8	7	6	5	4	3	2	**1**	②	3	4	5	6	7	8	9	STRESS-E

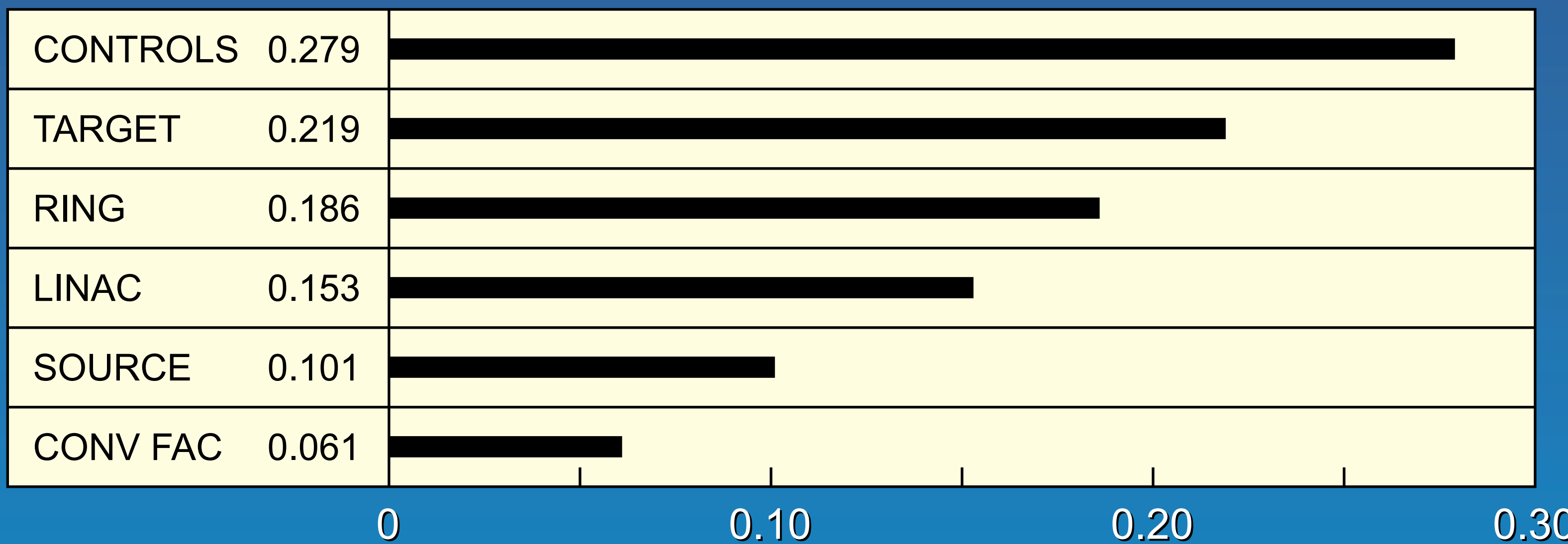
1=Equal 3=Moderate 5=Strong 7=Very Strong 9=Extreme

Compare Subprojects with Respect to Complexity: Example

1	SOURCE	9	8	7	6	5	4	3	2	**1**	2	(3)	4	5	6	7	8	9	LINAC
2	SOURCE	9	8	7	6	5	4	3	2	**1**	2	(3)	4	5	6	7	8	9	RING
3	SOURCE	9	8	7	6	5	4	3	2	(**1**)	2	3	4	5	6	7	8	9	TARGET
4	SOURCE	9	8	7	6	5	4	3	2	**1**	2	3	4	5	(6)	7	8	9	CONTROLS
5	SOURCE	9	8	7	6	5	4	3	2	(**1**)	2	3	4	5	6	7	8	9	CONV FAC
6	LINAC	9	8	7	6	5	4	3	2	(**1**)	2	3	4	5	6	7	8	9	RING
7	LINAC	9	8	7	6	5	4	(3)	2	**1**	2	3	4	5	6	7	8	9	TARGET
8	LINAC	9	8	7	6	5	4	3	2	**1**	2	(3)	4	5	6	7	8	9	CONTROLS
9	LINAC	9	8	7	6	5	4	(3)	2	**1**	2	3	4	5	6	7	8	9	CONV FAC
10	RING	9	8	7	6	5	4	(3)	2	**1**	2	3	4	5	6	7	8	9	TARGET
11	RING	9	8	7	6	5	4	3	2	**1**	2	(3)	4	5	6	7	8	9	CONTROLS
12	RING	9	8	7	6	5	4	(3)	2	**1**	2	3	4	5	6	7	8	9	CONV FAC
13	TARGET	9	8	7	6	5	4	3	2	**1**	2	3	4	5	(6)	7	8	9	CONTROLS
14	TARGET	9	8	7	6	5	4	3	2	(**1**)	2	3	4	5	6	7	8	9	CONV FAC
15	CONTROLS	9	8	7	(6)	5	4	3	2	**1**	2	3	4	5	6	7	8	9	CONV FAC

1=Equal 3=Moderate 5=Strong 7=Very Strong 9=Extreme

Example Ranking for Mean-Time-Between-Failure, z_i (Overall inconsistency index = 0.0)



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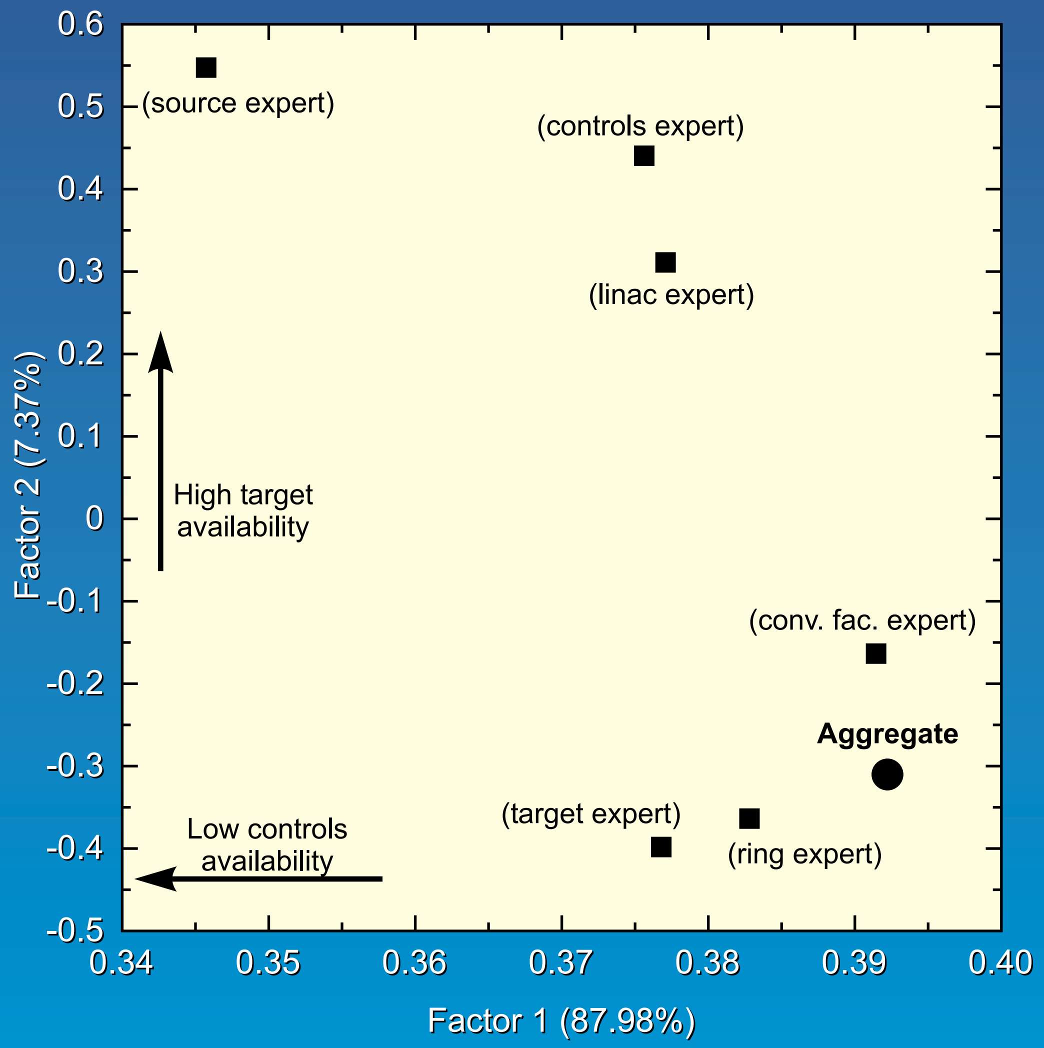
Principal Component Analysis Shows Agreement Between Experts and Aggregate Apportioned Availability



Summary Availability by Accelerator

	Source	LINAC	Accum. Ring or Rapid Cyc. Syncro	Target	Controls	Conv. Facilities	Physics Hours (h/year)	Overall Availability
Accelerators								
ISIS [a]	97.6%	95.5%	94.6%	99.4%	99.2%	99.0%	2741 (1994-1997)	86.8%
LANSCE H+ [b]	95.8%	94.3%		97.9%	99.3%	98.7%	2468 (1997)	86%
CERN (SPS) [c]			91.3%	99.0%	97.9%	97.7%	2953 (1998)	78%
AGS [d]	97.8%	88.5%	88.4%		96%	95.6%	3830 (1998)	
TJNAF [e]	98%		89% (minus cryo)		94%	98%	~6815 (1999)	77.8%
Storage Rings								
APS [f]	>100%		94.3%		99.5%	99.3%	4194 (1998)	93.2%

Note: IPNS availability funding limited rather than machine limited.

References: a) P. Gear, C. Piaszczyk, ISIS operation data sheets summary 1994-97
b) M. Erikson, Thesis
c) Colin, M. et.al., "1998 SPS & LEP Machine Statistics", doc. SL-Note 98-068 OP
d) J. Negrin e-mail 6/7/99
e) S. Suhring, e-mail 6/15/99
f) R. Gerig, e-mail 6/10/99

Summary

- Overall this is an innovative new method for apportioning facility requirements at the conceptual design stage when details are not known
- The apportioned availability among systems represents each experts opinion well in the example SNS application
- The approach imposes higher requirements on those systems in which an incremental increase is easier to achieve, and lower requirements where an increase is more difficult and costly