Establishing Availability Requirements Using Characteristics Factors and Expert Opinion

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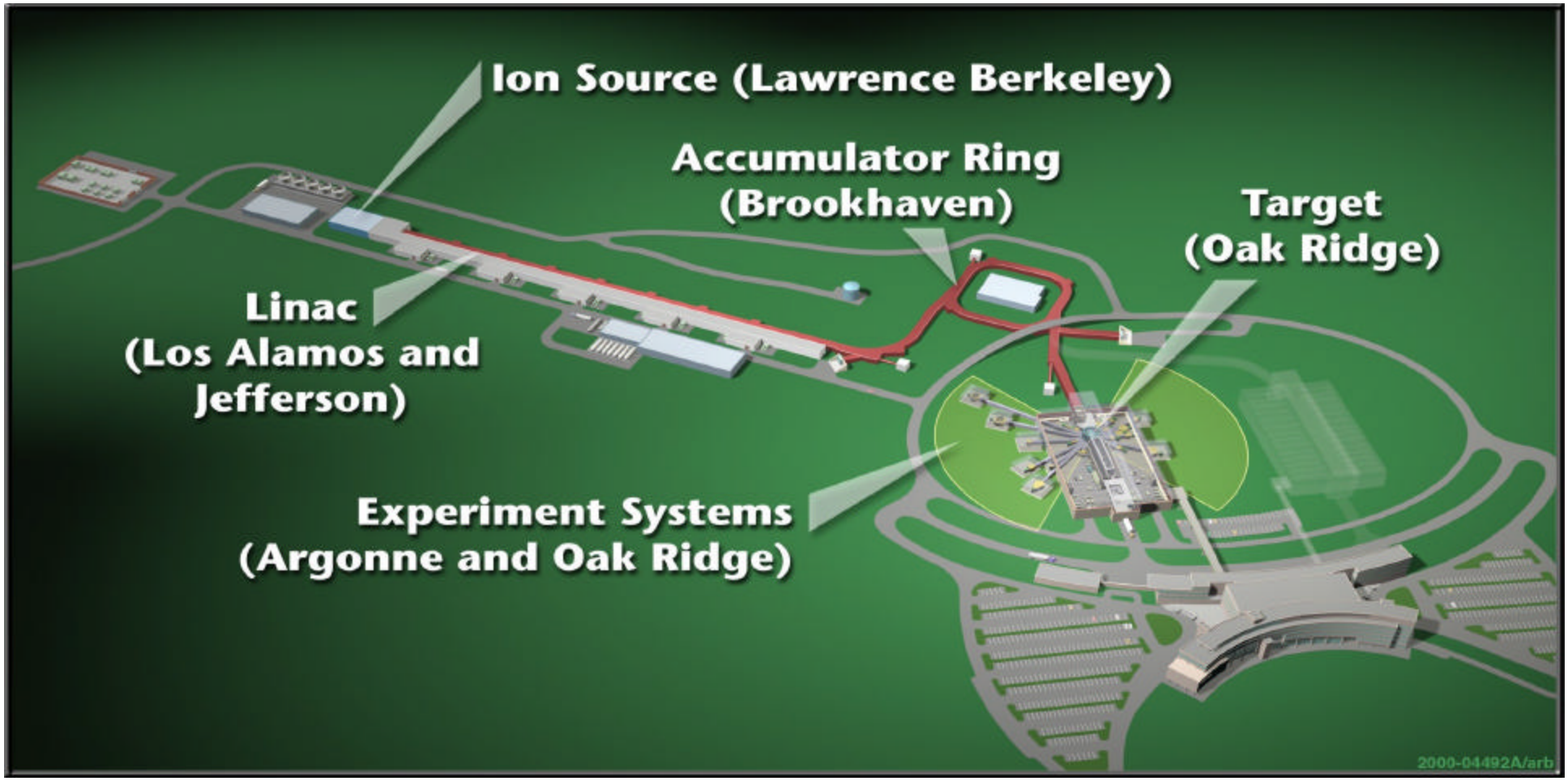
The Spallation Neutron Source



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			Score
	Cost	Technical Approach	Experience	
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 ith system**

θ_i = **mean time between failure for the ith system**

R_i = **mean time to repair for the ith 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%

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

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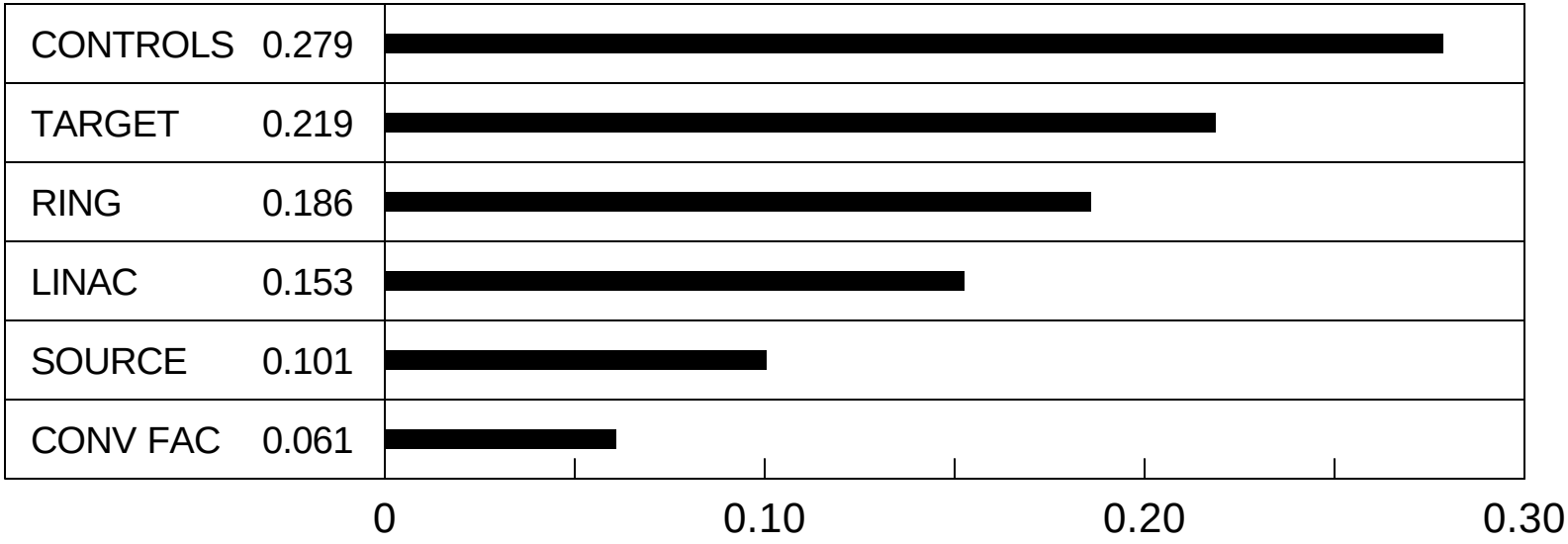
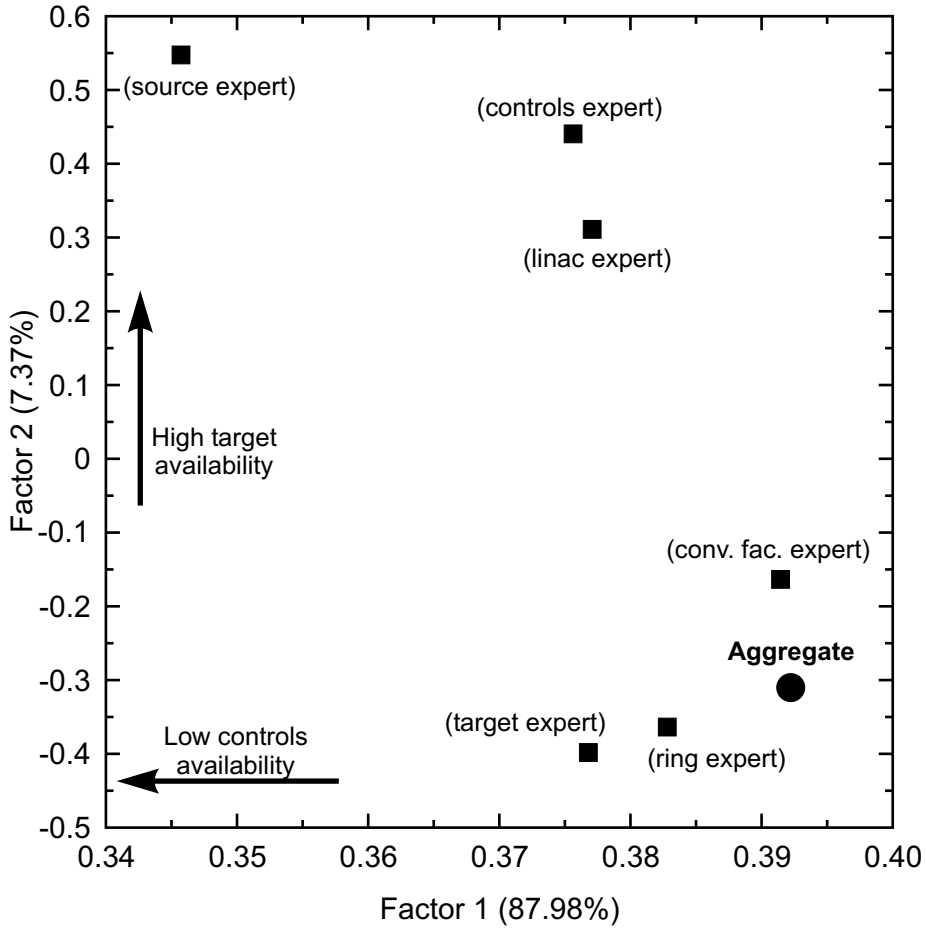
Example Ranking for Mean-Time-Between-Failure, z_i (Overall inconsistency index = 0.0)



ORNL DWG 99C-287R

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**