

Decision-Making by Technical Expert Committees for Engineering Systems

ESD Symposium

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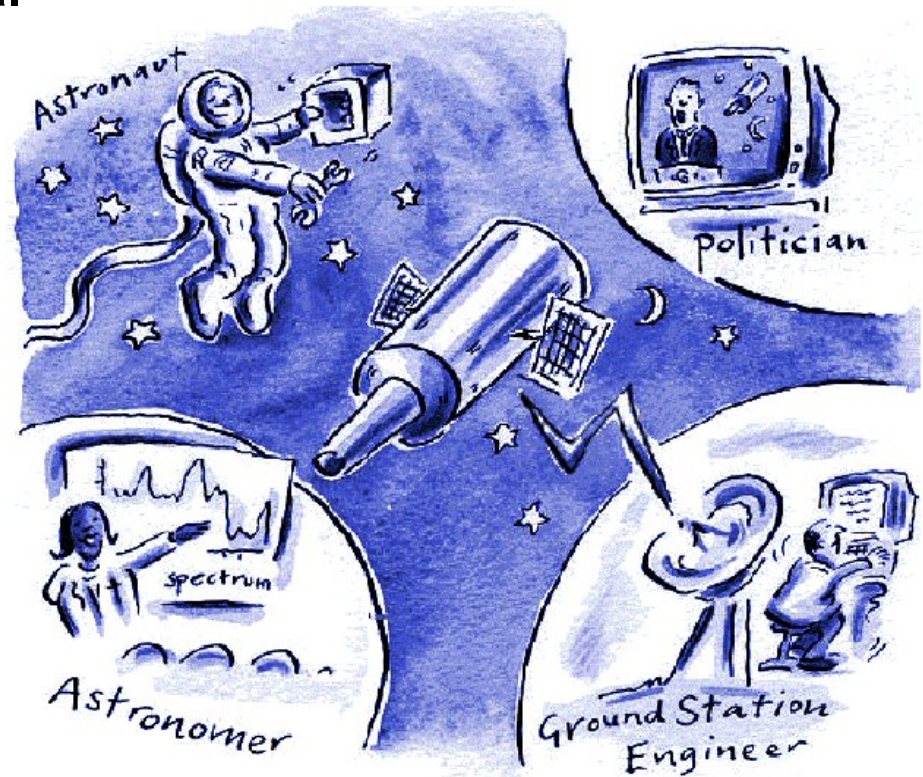
Committee: Prof. Chris Magee

Prof. Maria Yang

Dr. Joe Coughlin

Multi-Stakeholder Decisions in Engineering Systems

- Large-scale engineered systems are too complex for one individual to comprehend
 - **Insufficient cognitive capacity** of one architect
- Necessitates creation of **multiple specialties**
 - Each specialist has **expertise** from a **different domain**
 - Specialized **training** leads to **acculturation** in professional **institution** (Douglas 1986)
 - Each expert possess **different views** and **languages**
- System is "**boundary object**"
(Carlile and Schoonhoven 2002)



Source:

http://easyweb.easynet.co.uk/~iany/consultancy/stakeholder_taxonomy/space_telescope_cartoon.jpg

Expert Committee Decision-Making: Boundaries are Contested (Jasanoff 1987)

- Committees exist to pool knowledge
- Literature:
 - Social/Rational choice (Arrow 1963, Gaertner 2009, Visser & Swank 2007, von Neumann and Morgenstern 1944, Morrow 1994)
 - Quantitative & analytical/theoretical
 - Voting outcome dictated by preferences and strategic interaction
 - Currently treats all experts as homogenous
 - Organizational Psychology (Mohammed 2001, Mohammed & Ringseis 2001, Klimoski & Mohammed 1994, Winquist & Larson 1998, Kameda et al. 1997)
 - Empirical
 - Group decisions as information processing mechanisms
 - Decisions driven by *shared* information
 - Expertise is unshared by definition!
 - **Cognitive centrality** enables sharing information through **translation across boundaries** (Kameda et al. 1997)
- *Conclusion: Social structure impacts social dynamics!*

What Dictates Boundaries?

- Different perspectives & values make it difficult to generate consensus on interpretation of data

*"...all bring **distinct readings** of the evidence to decisions that may have heart-rending **implications for quality, cost, and fairness**..."*

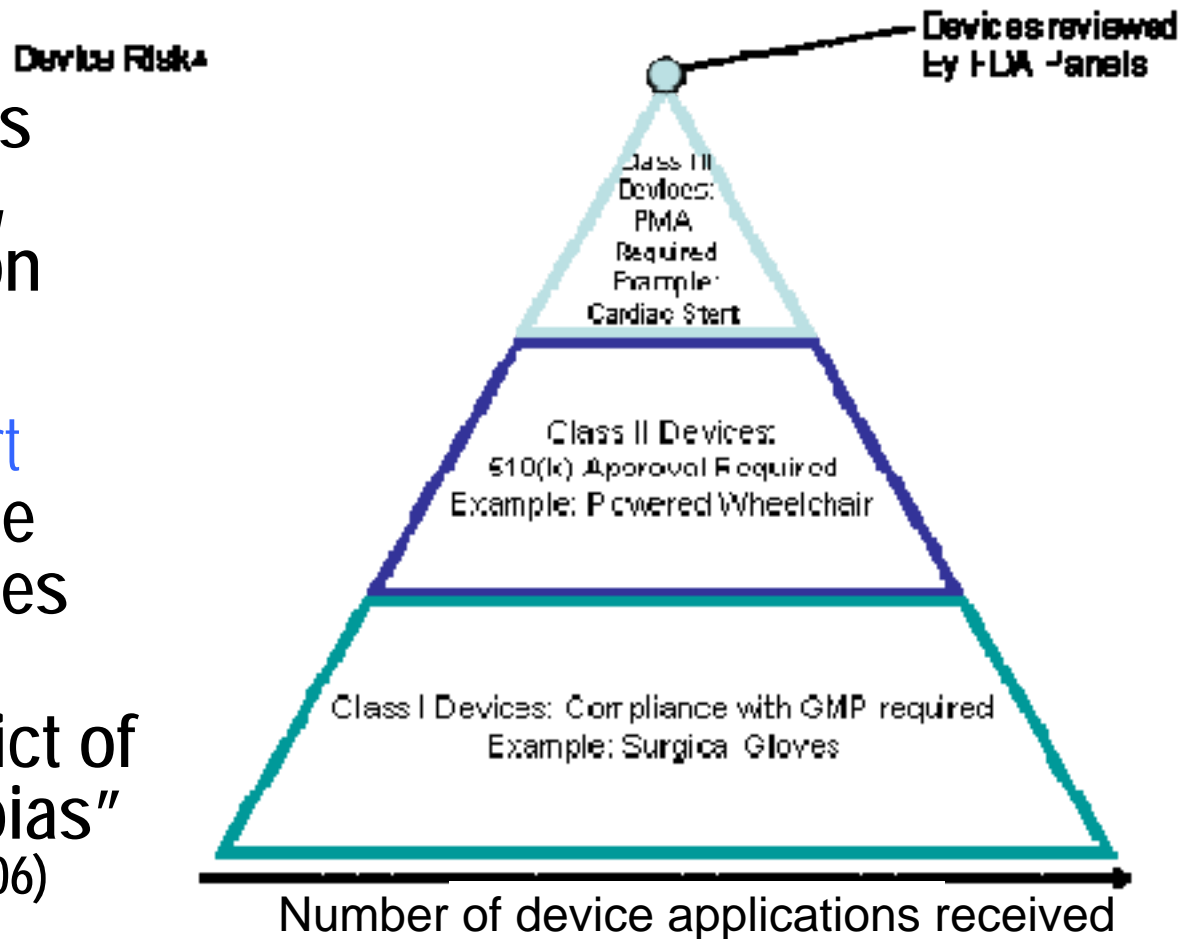
(Gelijns, Brown et al. 2005)

- Institutional Framing impacts interpretations of data
(Douglas 1986)
 - Risk perception is therefore socially constructed
 - **Institution**: e.g., a particular profession, specialty, or organization
 - Institutions **focus attention** towards **salient features**
 - Reflected in common **jargon**

(Brown 1986, Mulkey et al. 1987, Rapp 2000, Winner 1986, Collins & Evans 2009, Cohn 1987, Cobb & Elder 1987)

Medical Device Approval

- The Food and Drug Administration oversees medical device safety, efficacy and innovation
(Merrill, 1994)
- Interdisciplinary expert advisory panels oversee most innovative devices
(Sherman, 2004)
- Concerns about conflict of interest & “specialty bias”
(Friedman 1978; Lurie et al. 2006)



Data Source: FDA Advisory Panel Meeting Transcripts

- **Data availability:** Convenient unit of analysis; hundreds of potential samples
 - 21 committees over 11 years with ~2 meetings per year
- **Data consistency & validation:** Committee members' votes are recorded in “**court-reported**” transcript & minutes
- **Relevance to Problem:** Device approval is a group decision with uncertain consequences within complex socio-technical system
- **Domain Relevance:** FDA currently revising its advisory panel procedures, device evaluation criteria and conflict of interest rules

(Lurie et al. 2006)

Approach: Studying Institutional Background via Language

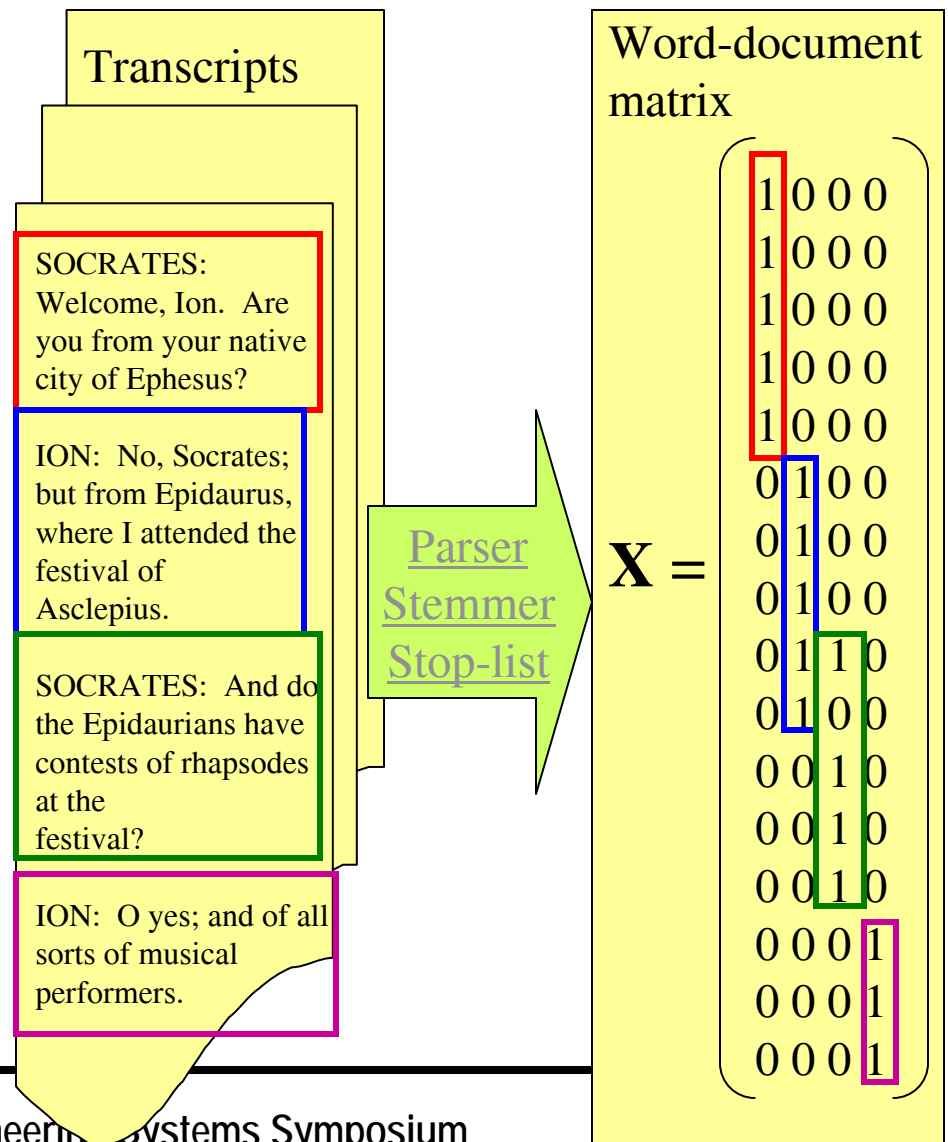
- **Group membership** influences perception of data
(Douglas and Wildavsky 1982; Elder and Cobb, 1983)
- **Group membership is reflected in language** (problem definition; jargon; symbolic redefinition)
(Douglas and Wildavsky 1982; Cobb and Elder, 1983; Elder and Cobb, 1983; Nelson 2005)
- **Analysis of language use patterns** provides insight into institutional frames
(Nelson 2005; Cobb and Elder, 1983; Elder and Cobb, 1983)
- **Use of Natural Language Processing** algorithms – e.g., Bayesian Topic Models
(Blei, Ng & Jordan 2003)

Bayesian Topic Models

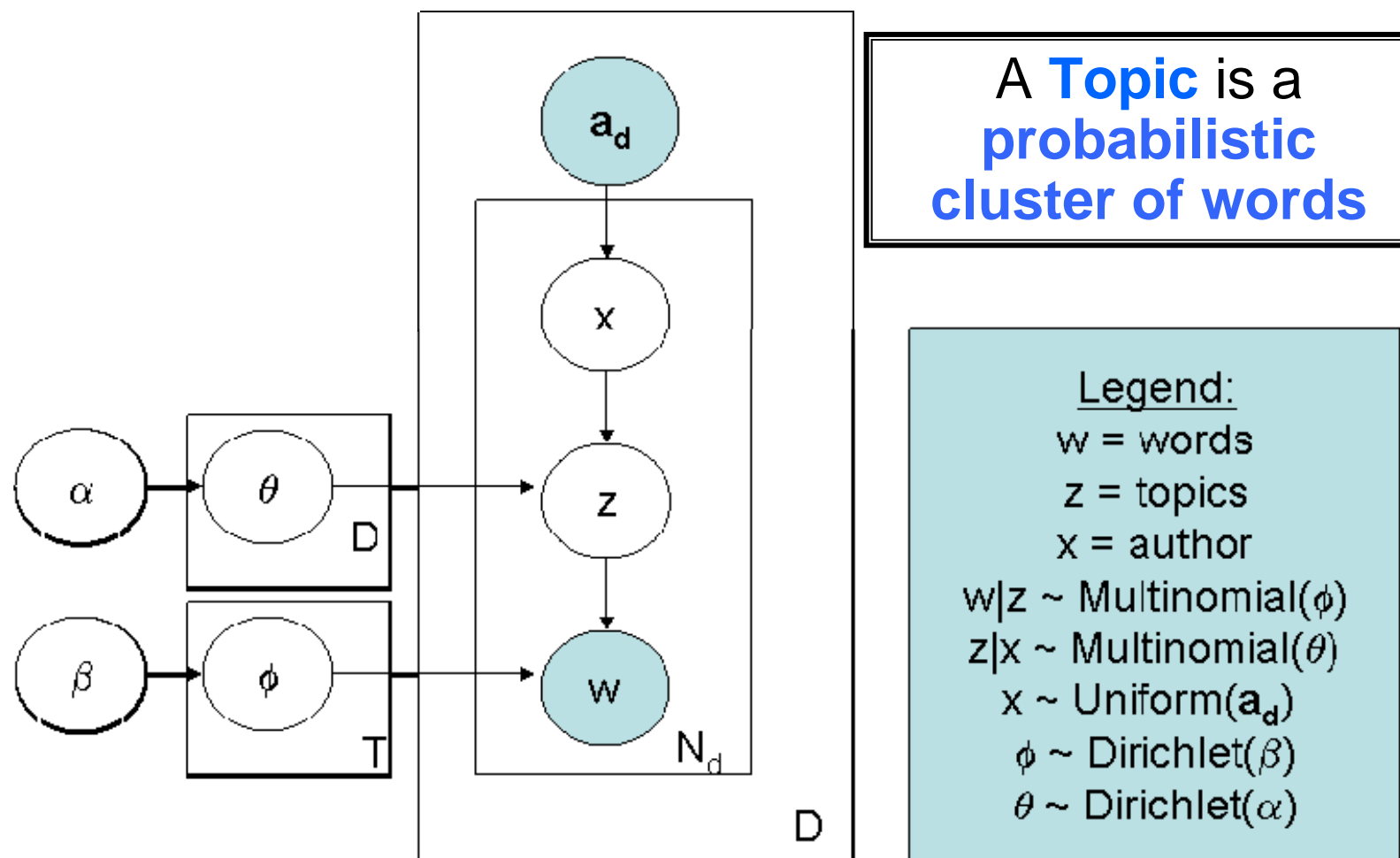
- **Bayesian probabilistic clustering**
 - Originally developed for information retrieval and document summarization.
- **Variants have been applied to**
 1. Analysis of structure in scientific journals (*Griffiths and Steyvers 2004*)
 2. Finding author trends over time in scientific journals (*Rosen-Zvi et al., 2004*)
 3. Topic and role discovery in email networks (*McCallum et al. 2007*)
 4. Analysis of historical structure in newspaper archives (*Newman and Block 2006*)
 5. Identifying influential members of the US Senate (*Fader et al. 2007*)
 6. Group discovery in socio-metric data (*Wang et al., 2005*)
 7. Also applicable across fields (e.g., genomics)
- Enables **consistent** analysis of large numbers of texts
- Assumptions are **explicit** and **transparent**

Data Pre-Processing

- FDA Transcripts are divided into **utterances**
 - One paragraph in length, as defined by court-recorded
 - Typically conceptually coherent
- Words are **stemmed**; **stop-words** are removed
- Utterances are parsed into a **word-document matrix**

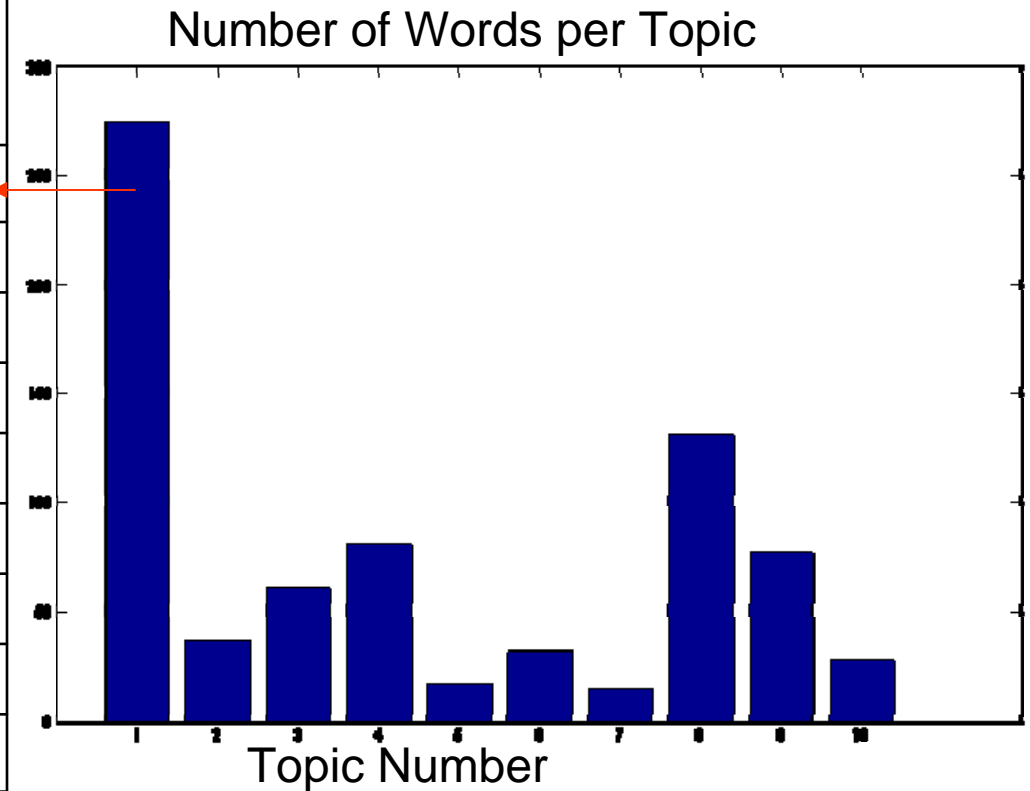


The Author-Topic Model (Rosen-Zvi et al., 2004)



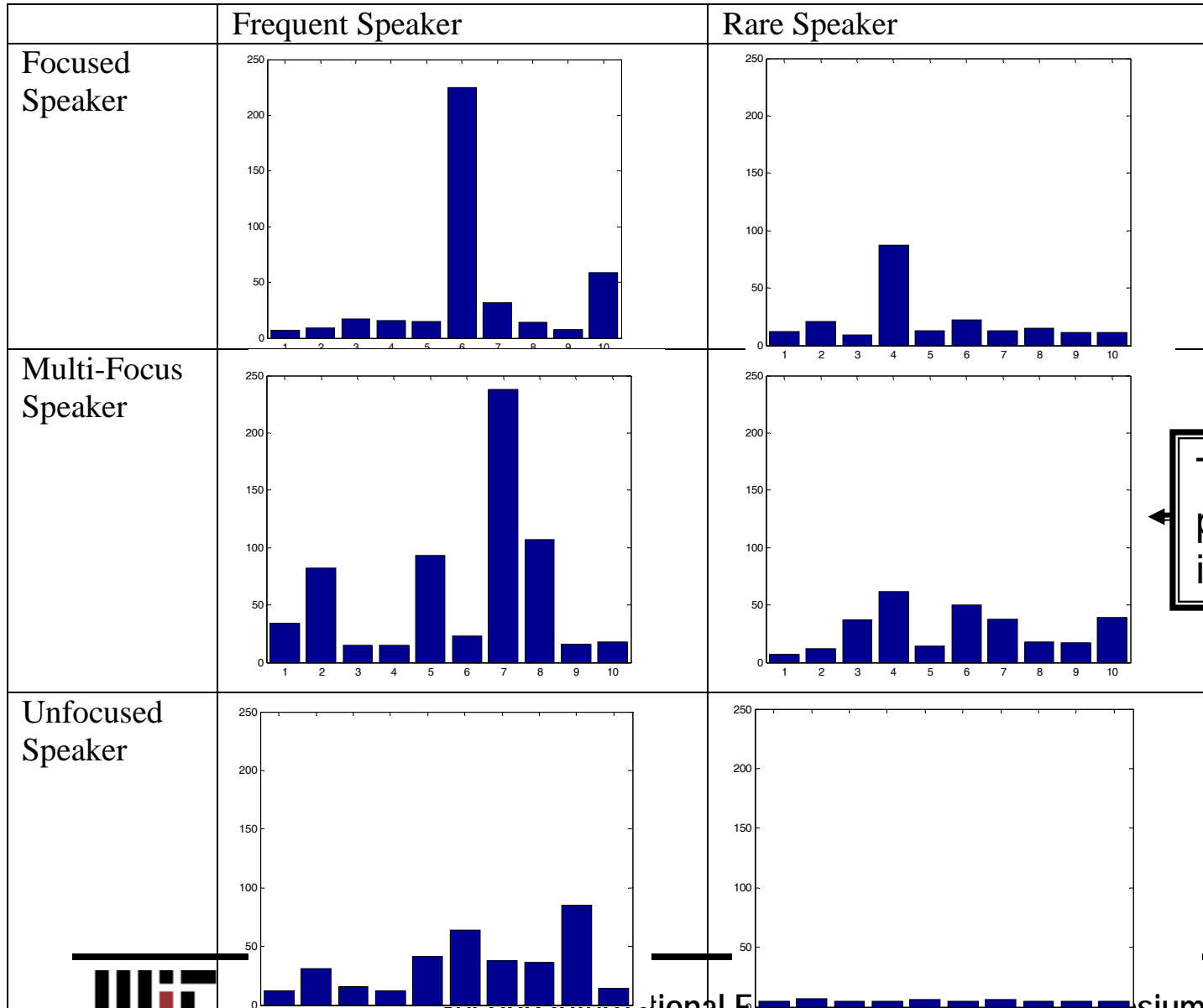
AT Model Results

Topic Number	Top Five Word-Stems
1	'clinic endpoint efficaci comment base'
2	'trial insync icd studi was'
3	'was were sponsor just question'
4	'patient heart group were failur'
5	'devic panel pleas approv recommend'
6	'think would patient question don'
7	'dr condit vote data panel'
8	'effect just trial look would'
9	'lead implant complic ventricular event'
10	'patient pace lead were devic'



Author profile for Dr. Konstam, March 4th, 2002

Sample AT Model Output



These speakers are potentially interdisciplinary



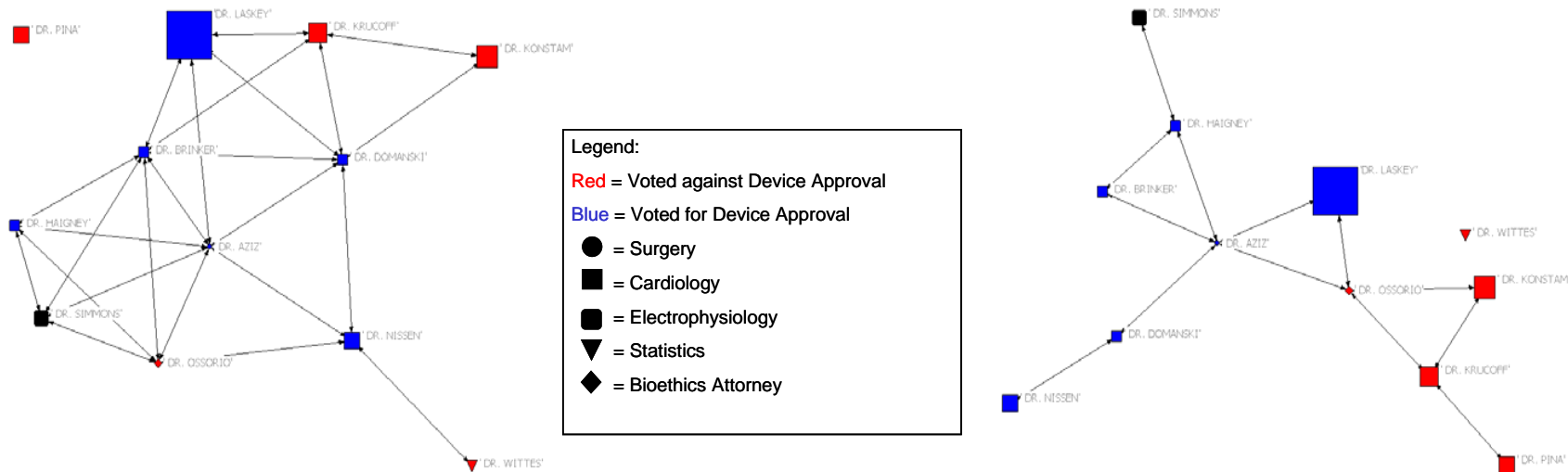
Generation of Social Networks

- Each **author is a node** in the network
- For each Author pair, does that pair's joint probability of speaking about the same topic exceed what is expected under a uniform distribution?

$$P(X_1 \cap X_2) = \frac{\sum_i^T P(Z = z_i | X_1) * P(Z = z_i | X_2)}{\sum_I^T \sum_j^T P(Z = z_i | X_1) * P(Z = z_j | X_2)} > 1/(\#_topics)$$

- If so, the **author pair is linked** in this probabilistic iteration

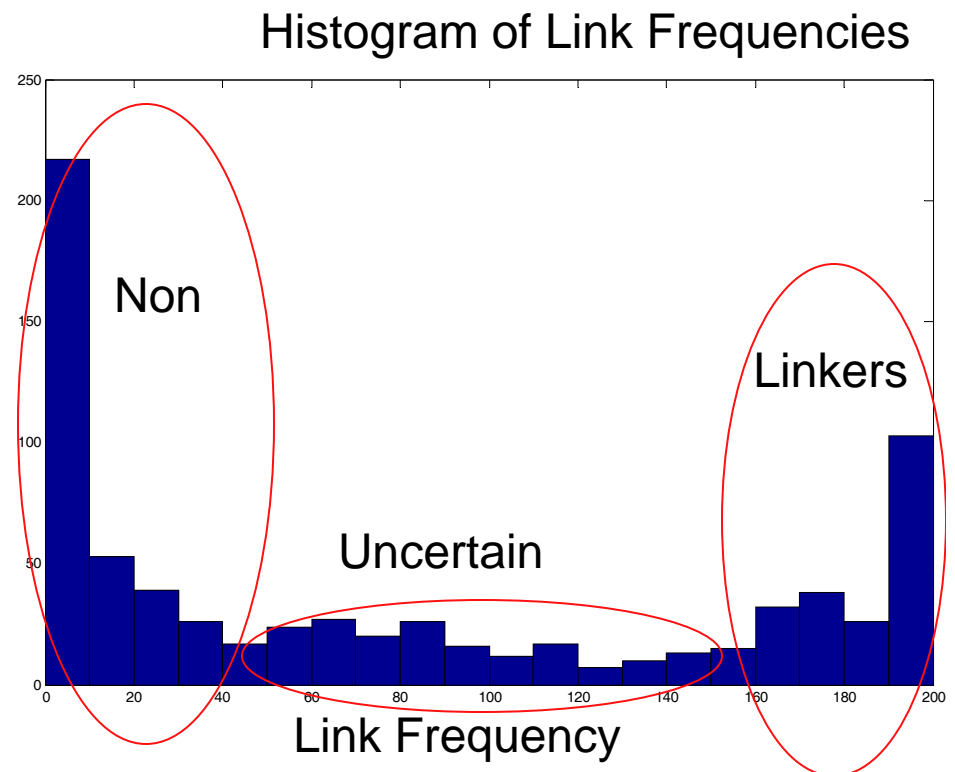
Author-Topic model is Probabilistic



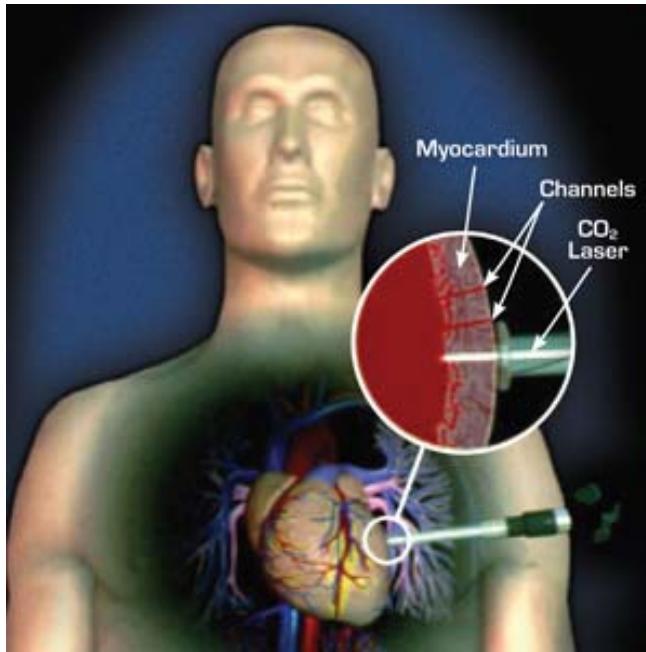
- **Result: Different samples from the model will yield different networks**
 - Each of these represent draws from a *distribution* over possible network topologies
 - We would like to find an aggregate representation
 - Took 10 samples from each of 20 starting random seeds = 200 samples

How to construct a network?

- Each author pair links a certain number of times over all AT samples
 - Number of links is link frequency
- Histogram of link frequencies shows bimodality.
 - We would like to construct a network out of the frequent linkers
 - Establish strong threshold at 95% and weak threshold at 90%



PLC CO2 Heart Laser System



<http://www.healthimaging.com/images/stories/CVB0206/CVB020604.jpg>

PLC Medical Systems, Inc. pioneered the CO2 Heart Laser System, which cardiac surgeons use to perform CO2 transmyocardial revascularization (TMR) to alleviate symptoms of severe angina.

Device was previously not approved by the committee due to insufficient data and was coming for repeat review.

Grouping by Specialty (I)

◇ 'DR. SIMMONS'
 □ 'DR. CASCCELLS'

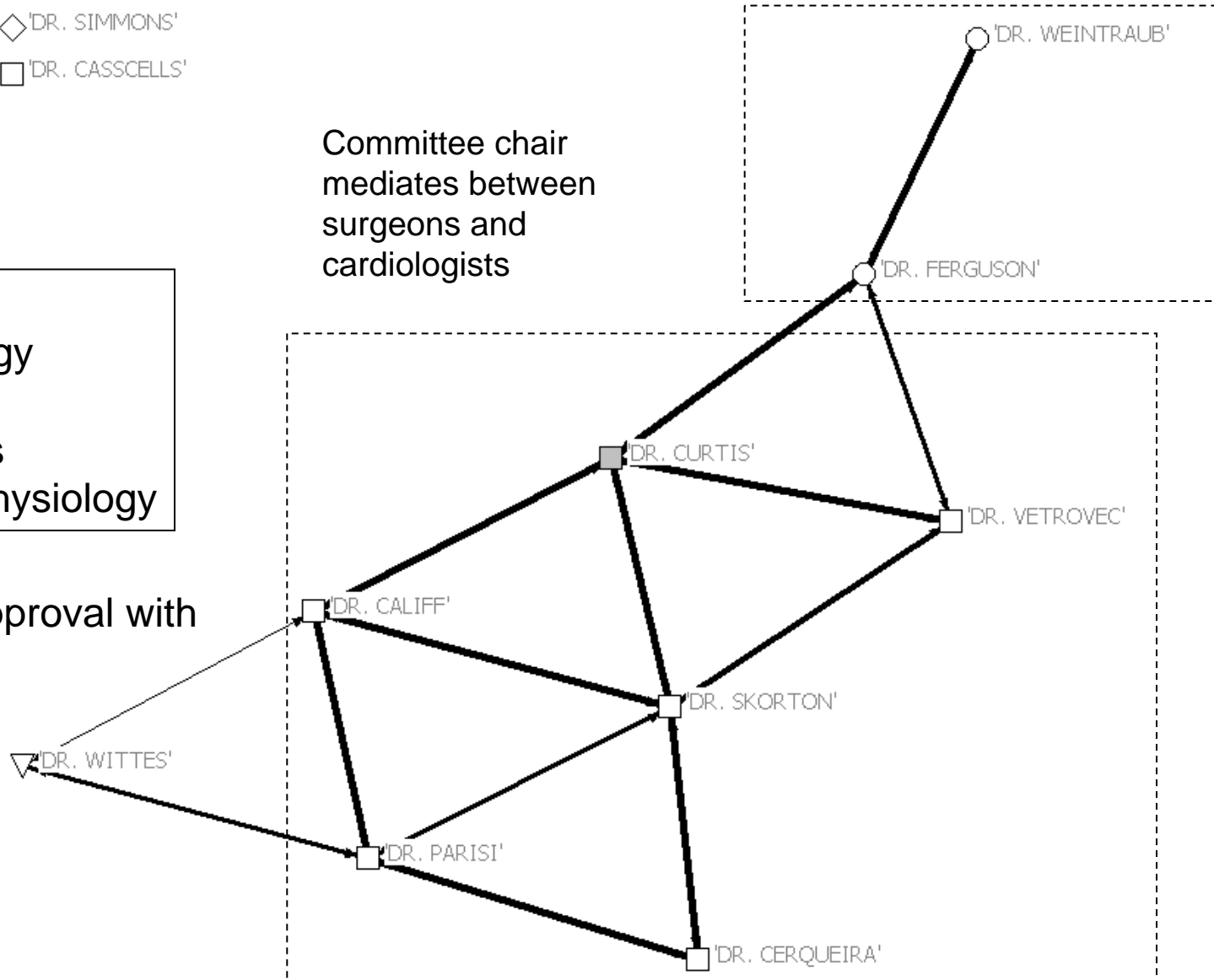
Legend:

- = Cardiology
- = Surgery
- ▽ = Statistics
- ◇ = Electrophysiology

04/24/98

Consensus approval with
 Conditions

7:15



Grouping by Specialty (II)

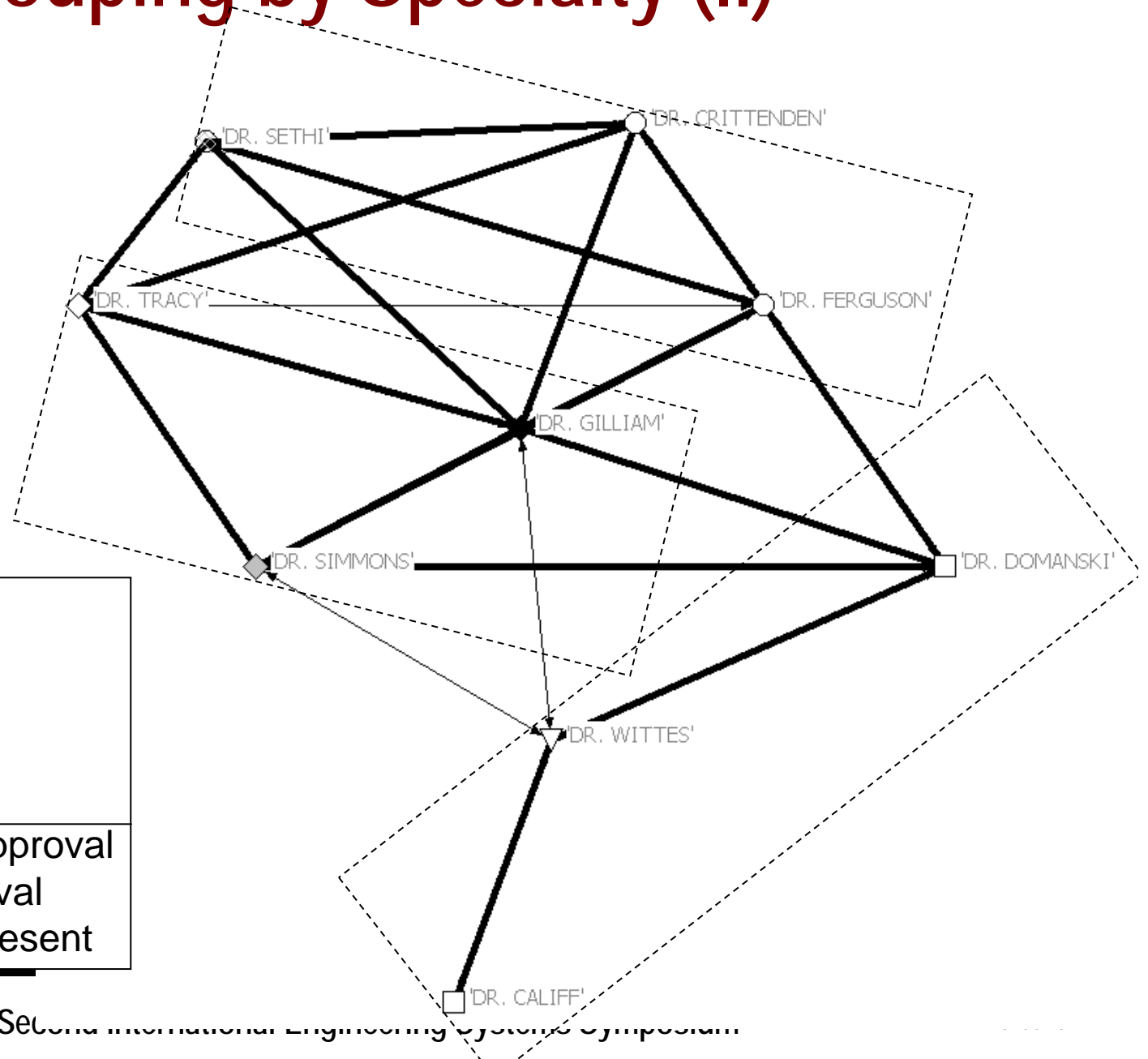
10/27/98

Approval With
Conditions

6/1/1

8:00

Eclipse Surgical Technologies, Inc.
TMR 2000 Holmium Laser System

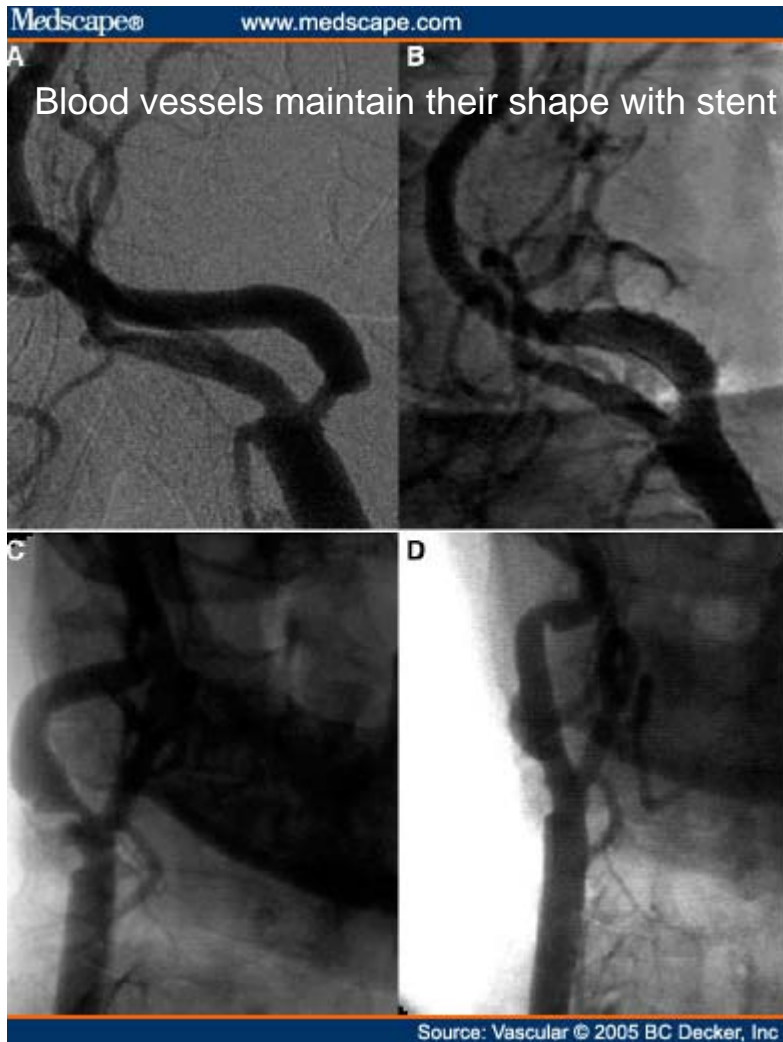


Legend:

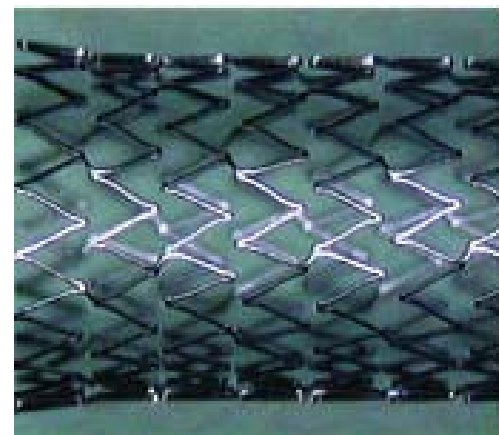
- = Cardiology
- = Surgery
- ▽ = Statistics
- ◇ = Electrophysiology
- = Against Device Approval
- = For Device Approval
- ▣ = Abstention/Not-Present



Cordis PRECISE Nitinol Stent System



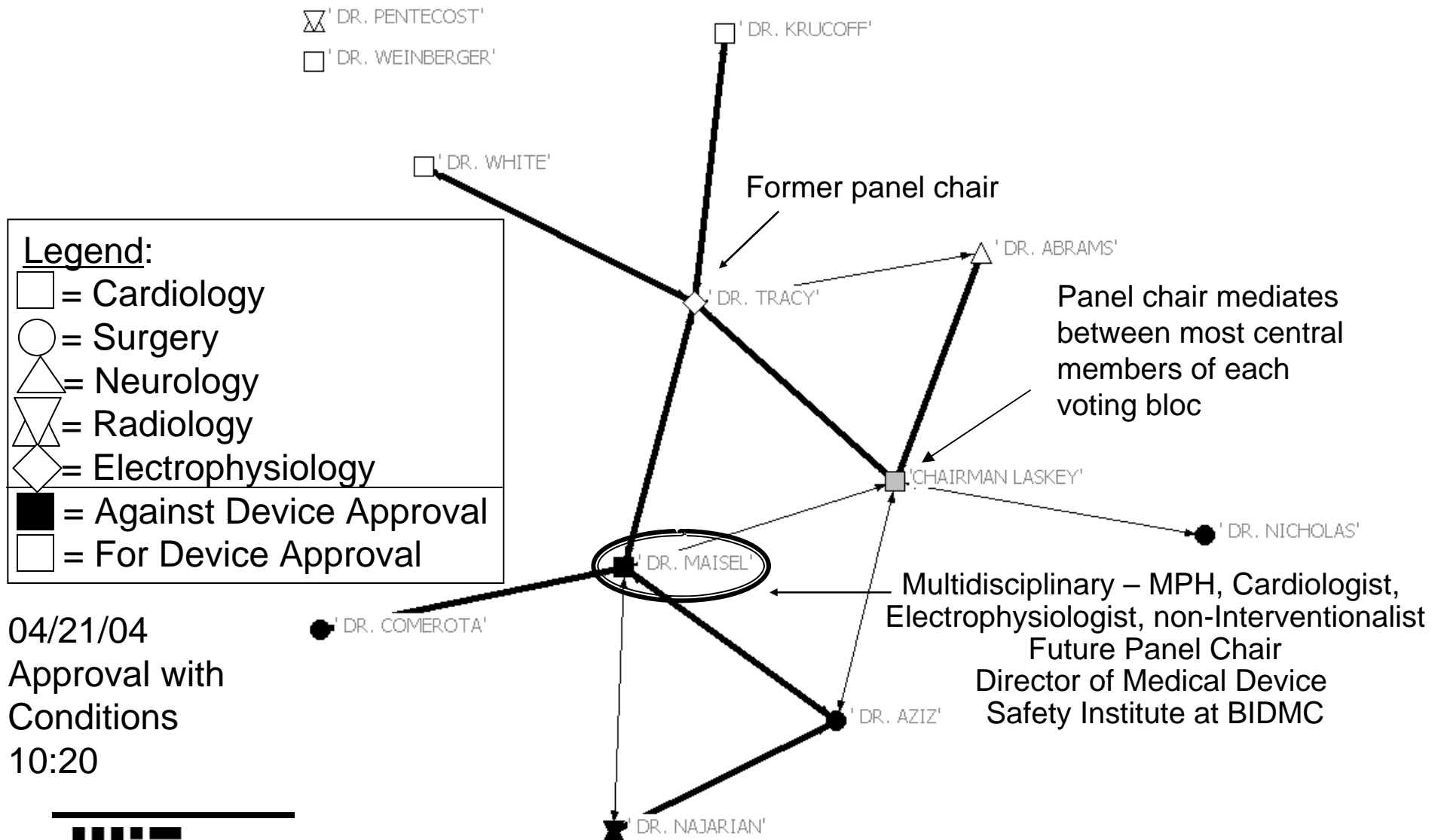
- Device replaces high-risk surgical endarterectomy with stenting procedure (performed by interventional cardiologists)
- Nitinol Stent, for tortuous anatomy, is flexible at cost of longitudinal strength



<http://img.medscape.com/fullsize/migrated/513/447/vas513447.fig2.jpg>

http://www.evtodayarchive.com/etart/ET0903/saph_archer_addl.jpg

Grouping by Votes

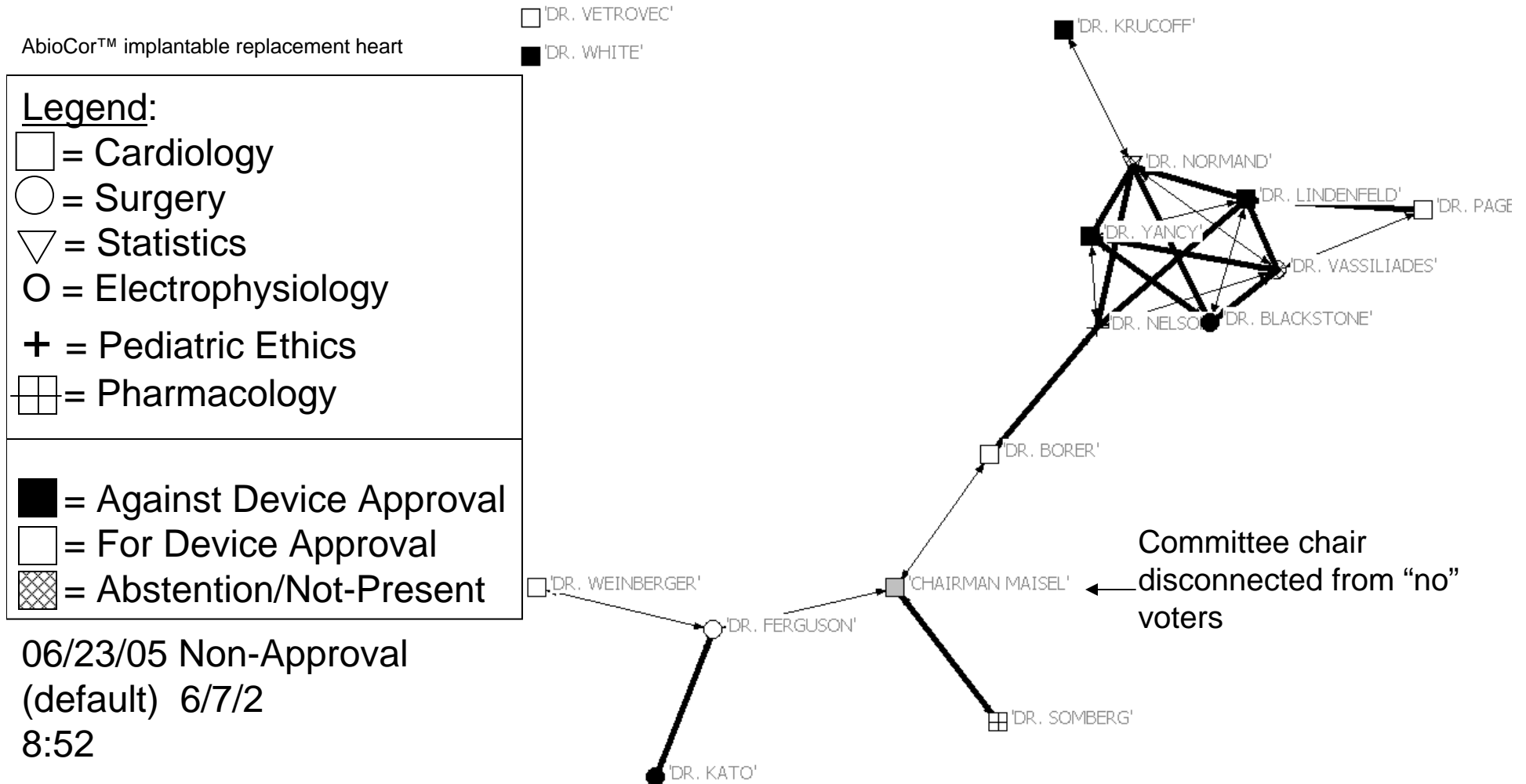


Abiocor Implantable Replacement Heart



- Application for Humanitarian Device Exemption (HDE)
- Proposal to grant exemption was voted down
 - No counter-proposal made
 - Panel came to no official recommendation
- FDA ultimately granted the HDE in September 2006

Grouping By Another Identity



Summary

- **Preliminary conclusions:**
 - Language use reflects institutional identity
 - In absence of controversy, medical specialty is primary identity
 - No need for cross-boundary learning (i.e. information sharing) to occur
 - When controversy is present, committee members may learn from one another
 - Medical specialty identity is displaced by voting preference identity
 - Often voting preference and medical specialty identities overlap; when they do not, another identity dominates – could provide insight into strongly-held values.
 - Understanding committee decision-making dynamics is crucial for the design and operation of complex engineered systems
 - These dynamics can be analyzed computationally