Innovation Metrics in U.S. Industry: A Historical Perspective

NSF Workshop on Innovation Metrics, June 6-7, 2006

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Overview of Presentation

- ASB Personal Background with Innovation Metrics
- State of the Art review of Innovation Metrics
  - By Elie Geisler for CIMS, 2002 (48 pp.)
  - Available at cims.ncsu.edu/research
- 20 Year's of IRI Contributions
  - 'R&D Returns' Framework-(1985)
  - 'R&D Productivity' Study-(1991)
  - IRI/CIMS Data Base Project-(1993-99)
  - Technology Value Pyramid Model (1995-ongoing)
- Metrics in Industry Today (Case Example)
- Closing Observations

- Personal Perspective
  - User of NSF R&D data since 1973
  - Member of NSF program staff 1973-83
  - Academic research using NSF/Census Bureau data since 1985
  - Collected industrial R&D statistical data from IRI member firms from 1991-1999
  - Studies of R&D impacts on productivity growth, stock market price movements

'R&D Metrics in Technology Driven Organizations?' A CIMS 'WDWK Report' by Elie Geisler, 2002

Topics Covered:

- Input Metrics (Brief Mention Only)
  - R&D Expenditures/Sales
  - R&D Expenditures/Patents
  - Internal vs. External R&D
  - Effectiveness Index
  - Cost per Scientist & Engineer
  - R&D Expenditures/Assets
  - R&D Expenditures/Exports
- See cims.ncsu.edu/research for pdf copy.

- Output Metrics (Detailed Assessment organized as follows)
  - Bibliometrics
  - Patents
  - Peer-Review
  - Economic & Financial
  - Process Outcomes
- Basis of Assessment:
  - Operational definition(s)
  - Applications
  - Strengths
  - Weaknesses

Geisler Paper Meta-Framework (From A. H. Rubenstein, 1989)

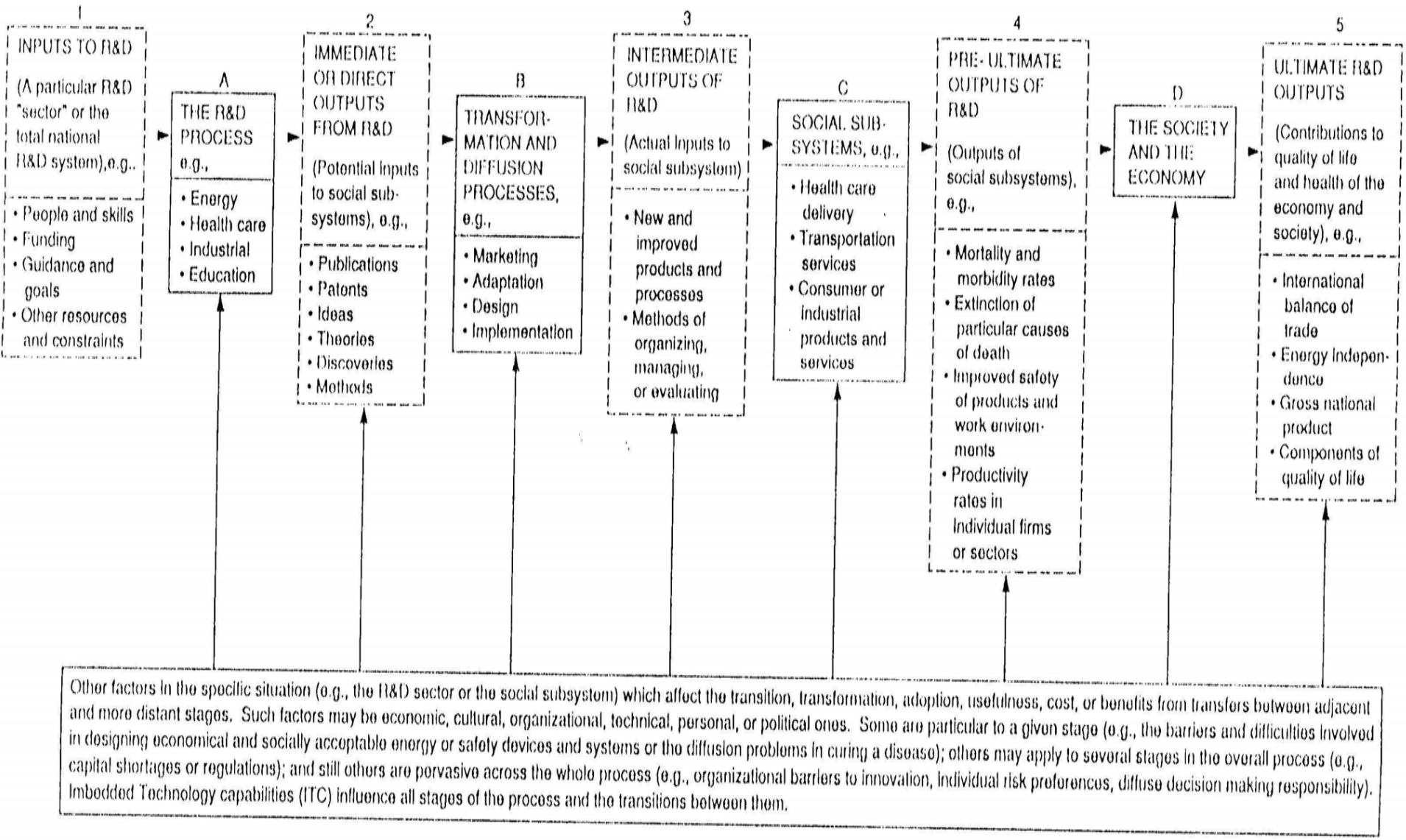


Figure 8-8. A preliminary conceptual model of the linkages between the R&D process and social systems.

Friedman's 10 'Flatteners'(Tom Friedman, 2005)

- 11/9/89-Fall of the (Berlin) Wall
- 8/9/95-When Netscape went Public
- Work Flow Software
- Open Sourcing
- Outsourcing
- Offshoring
- Supply Chaining
- Insourcing
- Informing
- The Steroids

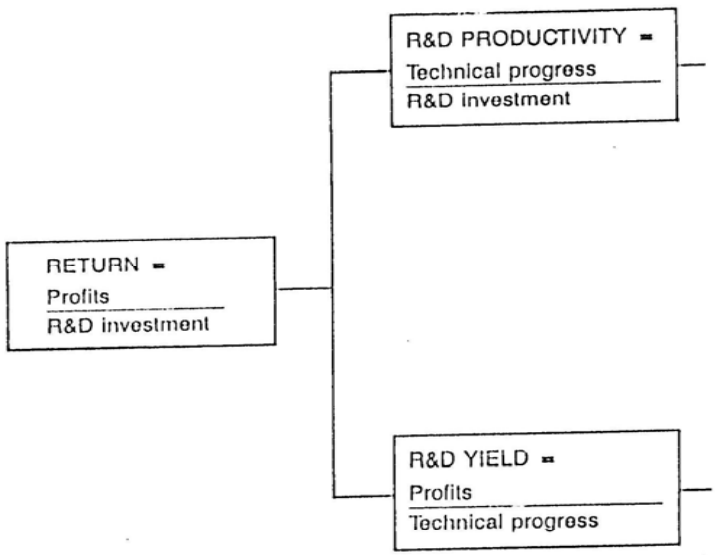
And Three 'Convergences'

20 Years of Innovation Metrics in the IRI

- 'R&D Returns' Framework – 1985 (Whiteley & Foster)
  - Links firm's profits to R&D investment
  - Decomposes R&D Investment into specific innovation activities
  - Defines **financial** output metrics attributable to R&D
    - NSR=New Sales Ratio
    - CSR=Cost Savings Realized
  - Stimulates surge of interest and experimentation in metrics throughout the IRI

From Whiteley & Foster

R&D RETURN, PRODUCTIVITY, AND YIELD FRAMEWORK



From Whiteley & Foster

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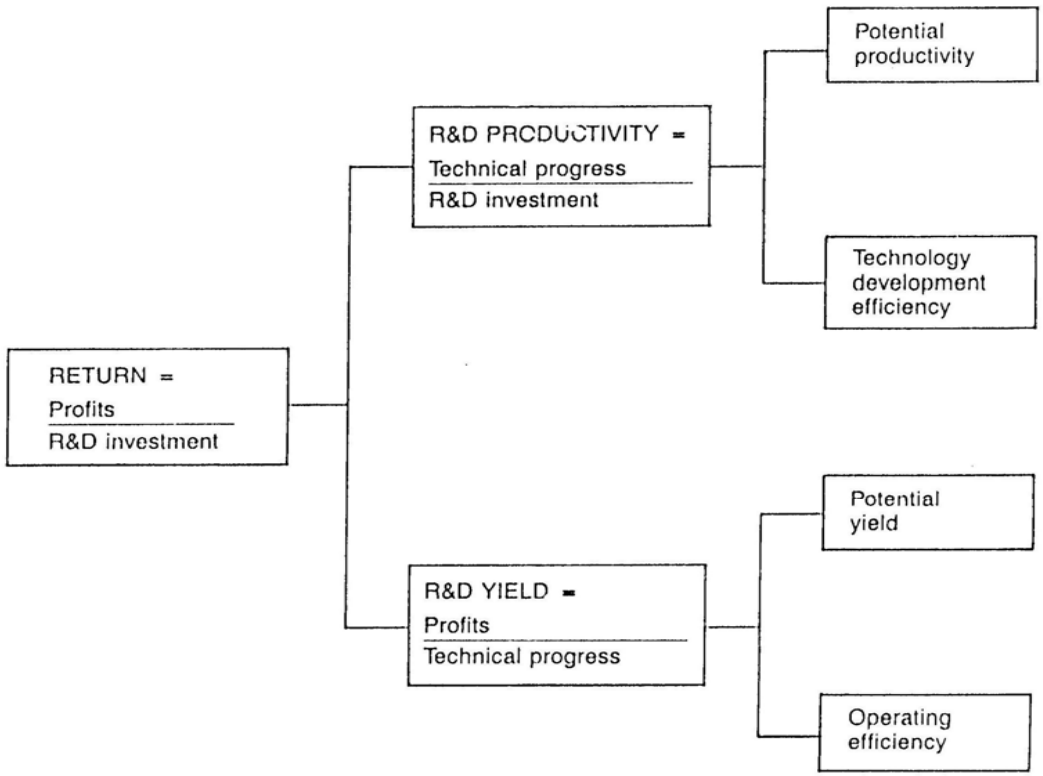
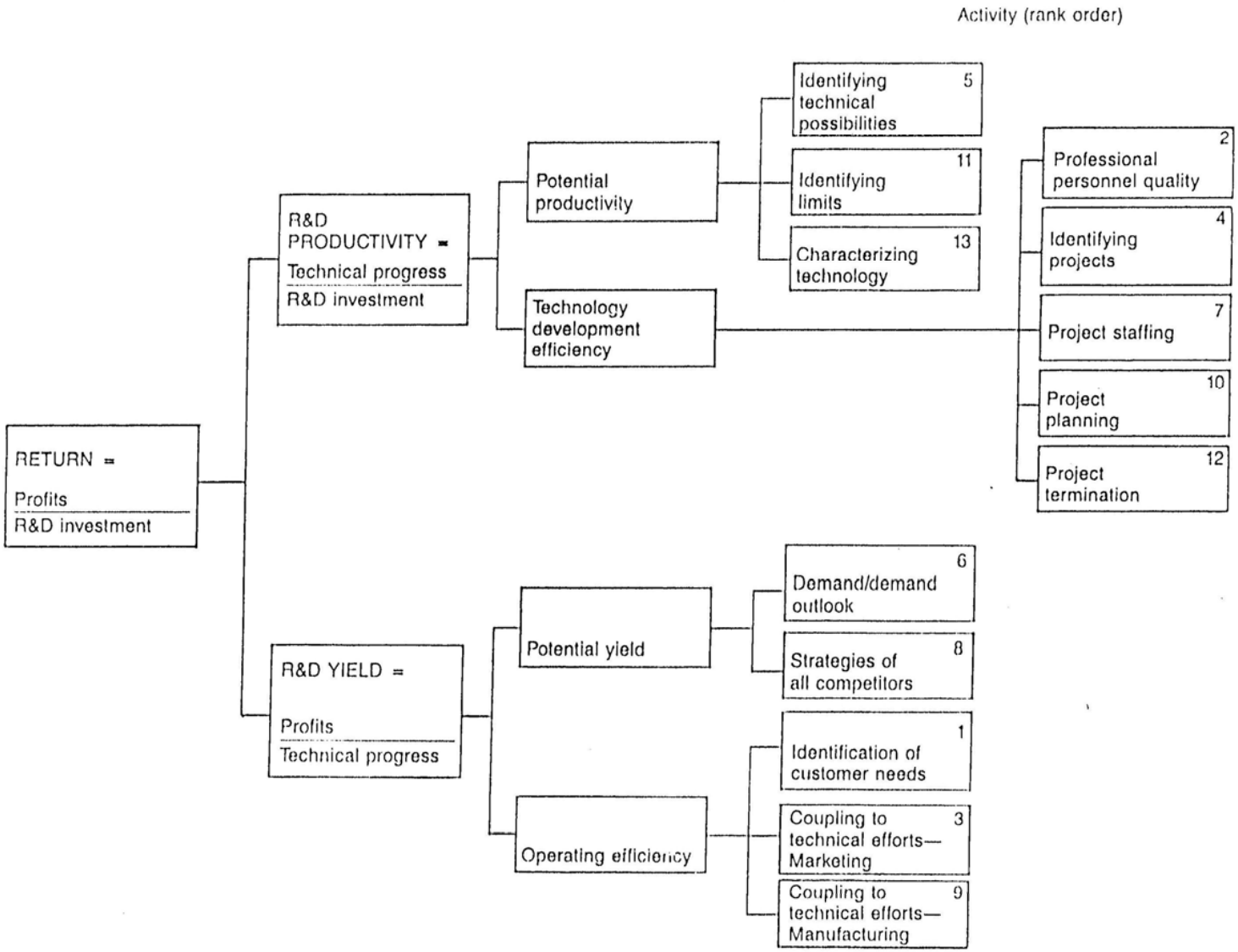


From Whiteley & Foster

R&D RETURN FRAMEWORK—HIGH RETURN ACTIVITIES



From Whiteley & Foster

IRI R&D FINANCIAL METRICS

$$\text{NSR} = \frac{\text{Revenues realized this year from new products introduced in last 5 years}}{\text{Total Revenues Realized this Year}}$$

$$\text{CSR} = \frac{\text{Cost savings realized this year from process improvements introduced in last 5 years}}{\text{Gross Profits Realized this Year*}}$$

$$\text{R\&D Yield} = \text{Gross Profits} \times (\text{NSR} + \text{CSR})$$

$$\text{R\&D Return} = \frac{\text{R\&D Yield}}{\text{R\&D Expenditures}}$$

*Gross Profits=Sales Revenues-Cost of Goods Sold

- TFP studies of IRI sample-’87-’91 (Zhao-PhD)
  - 12 chemical firms studied from 1969-1988
  - Computes TFP growth at the **firm** level
  - Significant relationship of TFP growth & R&D Intensity (R&D Expenditures/Sales)
  - Decompose R&D expenditures into BR, AR , PD, PCS, TS; find PD & PCS directly related to TFP
  - Path analysis shows BR & AR link to PD & PCS
  - ‘VERY TEDIOUS, THANKLESS WORK!’ (Zhao, 1991)

Research Topic

Relationship Between Corporate Performance And R&D Management Decisions and Practices

- Are firms that closely couple their technology strategies to their business strategies better performers?
- What "metrics" should be used to assess the contribution of technology to corporate performance?
- Do firms that invest more heavily in R&D perform better than their competitors?
- How do high and low performers differ in their technology management practices?
- Does the "composition" of the firm's R&D effort affect its competitive performance?

Bean:Reunion1

From Zhao, 1991

Total Factor Productivity Index

The Impact of Technology (R&D Input)
The 12 Nondrug Chemical Firms, 1969-1988

$$TFP\ Growth = a + b*(R\&D\ Intensity)$$

$$TFP\ Growth = 0.10 + 0.62 * (R\&D\ Intensity)$$
$$(0.01) \qquad (0.38) \qquad (standard\ error)$$

where:
a: is a constant parameter
b: is the impact of R&D input on TFP measuring as a marginal rate of growth

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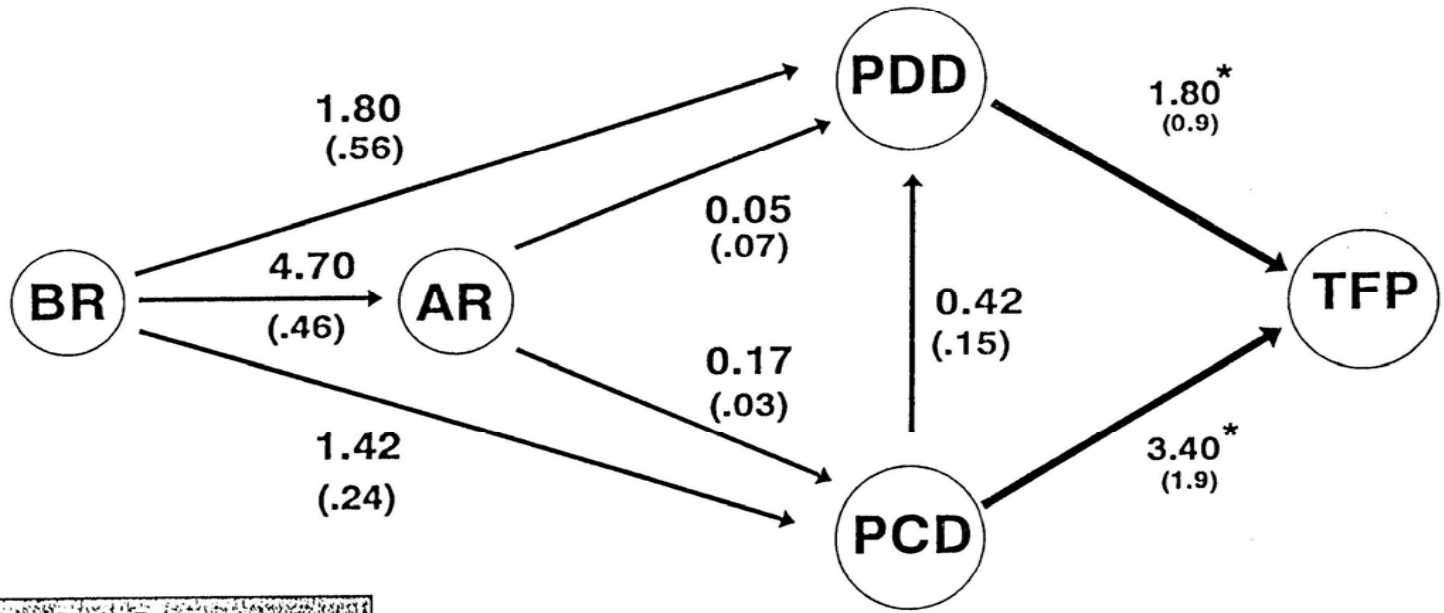
From Bean, Russo & Zhao, 1992

R&D Activities and Their Productivity Impact

CIMS 12 Non-Drug Chemical Firms, 1971-1988 (C)



BR: Basic Research
AR: Applied Research
PDD: Product Dev. Des. Eng.
PCD: Process Dev. Des. Eng.
TFP: Total Factor Productivity

Standard Errors In Parenthesis
* Estimated regression coefficients

CIMS Reunion
June 1992

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Bean:Reunion11(c)

- Launch IRI/CIMS Data Base Project (1990)
  - Triggered by McGraw-Hill decision to discontinue BW 'Annual R&D Scoreboard' Issue
  - IRI Subcommittee formed to assist CIMS
  - Annual survey of IRI membership (>220 US firms)
  - IRI R&D definitions compatible with NSF/Census except for 'Tech Service'
  - Both Firm and Line of Business data
  - Some output variables (NSR, CSR, Patents)
  - 27 directly measured metrics, 16 computed metrics feasible, and 10 additional feasible through clustering
  - Results reported in RTM annually (Jan-Feb) 1993-1999
  - Survey discontinued 1999 due to lack of IRI interest
  - Data file maintained & available through CIMS

From Bean, Whiteley & Russo, Research-Technology Management, 1996

Firm Segment or Laboratory Name _____	Laboratory Type L	Primary SIC Code S
1.Firm, Segment or Laboratory Profile		$Millions
a. Total Net Sales		F,S
b. Total R&D Expenditures		F,S,L
c. Gross Profit (Sales Revenue - Cost of Goods Sold)		F,S
2. Sources of R&D Funding		$Millions
a. Company Financed - Corporate Sponsored		F,S,L
b. Company Financed - Business Unit / Project Sponsored		F,S,L
c. Federal Government		F,S,L
d. Other Outside Contract		F,S,L
e. Total R&D Funds = (2a+2b+2c+2d)		F,S,L
3. R&D and Technical Service Expenditures by Activities		$Millions
a. Basic Research		F,S,L
b. Applied Research		F,S,L
c. Product Development		F,S,L
d. Process Development		F,S,L
e. Technical Service		F,S,L
4. Total R&D Expenditures by Expense Accounts		$Millions
a. Support Services (See instructions)		F,S,L
b. Technical R&D = (1b - 4a)		F,S,L
5. Distribution of R&D Personnel		Number
a. Total Personnel		F,S,L
b. Support Services Personnel		F,S,L
c. Technical R&D Personnel = (5a - 5b)		F,S,L
d. Technical R&D Personnel - PhDs and MDs		F,S,L
e. Technical R&D Personnel - Exempt (Including PhDs and MDs)		F,S,L
6. Innovation Performance		$Millions
a. What was your annual sales revenue in 1994 attributed to new or improved *products and services* commercialized during the period 1989-1993?		F,S
b. What was your annual sales revenue in 1994 attributed to new or improved *processes* commercialized during the period 1989-1993?		F,S
c. What were your annual cost savings in 1994 attributed to new and improved *processes* commercialized during the period 1989-1993?		F,S
7. Special Issues		($Millions)
a. What were your 1994 R&D expenditures required to meet compliance with health, safety and environmental regulations *within your own company?*		F,S
b. What were your 1994 R&D expenditures to *provide your customers with products* in compliance with health, safety and environmental regulations?		F,S
c. What were your 1994 R&D expenditures for developing software for new and improved product or process applications whether embedded or stand alone?		F,S
d. What were your 1994 R&D expenditures to support outside contracts for R&D at colleges, universities, research institutes and consortia?		F
e. What were your 1994 R&D capital expenditures?		F
f. What was your R&D annual depreciation expense in 1994?		F
8. Patent Performance		Number
a. How many U.S. patents were granted to your firm in 1994?		F
b. How many Non-U.S. patents were granted to your firm in 1994?		F

F, S, L = Information requested at the Firm Level, Segment Level or Laboratory Level

From CIMS internal records, c. 1996

SOME POSSIBLE USES OF THE DATA BASE

Question/Issue	Data Base Extensions	Primary Stakeholders
Relation Between Innovation Outcomes & Financial Outcomes Over Time (Firm)	Merge IRI Firm Data with Compustat Firm Data	2, 3, 4
Composition of R&D in the Firm vs. its Composition in Business Segments	None Needed, or Enrich with Compustat	2, 3, 4
Strategic Alignment of R&D with Business Needs: Shifts Over Time	None (PMP)	2, 3
"Value-Added" by R&D: Contributions to Economic Growth	Merge with Compustat, Gov't.	5
"Value-Added" by R&D: Contributions to Shareholder Wealth	Merge/Compare with Financial Data Sets	4
Relation Between Innovation Management Practices & Financial Performance	Merge IRI Firm Data with Ellis-Curtis Data & Compustat	1, 2
International R&D Benchmarking	Merge/Compare with International Partners Data	2, 5

The IRI's Technology Value Pyramid (1995)

- A hierarchal listing of managerial factors that link to strategic factors and to the financial outcomes of the corporation.
  - Extends the R&D returns framework of Whiteley & Foster
  - Includes and defines 33 metrics for tracking over time
  - Addresses information needs of 4 levels of stakeholders in the firm
    - CEO, Board of Directors, shareholders & financial community
    - Business managers
    - R&D managers
    - R&D staff
  - Currently under study by the IRI to assess member acceptance, utilization and currency of the metrics.
  - Ref: Tipping & Zeffren, 'Assessing the Value of Your Technology', RTM, Sept-Oct, 1995.

- Financial Studies ’85-Pres (Guerard & Bean)
  - Financial determinants of R&D spending by Corporations
  - Relation of R&D spending to Stock prices
  - Test of ‘Perfect Markets’ Hypothesis - rejected
  - Compustat Data (10K) cross checked w/NSF/Census data (Res. Policy, 1989)
  - Three stage least squares model works (1975-82)
  - Constructed Goal Programming model to guide R&D spending adjustments
  - Global data base from 1950-2004 now in place (per Guerard)

From Guerard, Bean & Andrews, 1987

R & D and Stock Prices

The relationship is complex:

$$PCS = f(\overset{+}{\text{Dividends}}, \overset{+}{\text{Capital Expenditures}}, \overset{+}{\text{R \& D}}, \overset{+}{\text{Book Value}})$$

But:

$$R\ \&\ D = f(\overset{+}{R\ \&\ D_{t-1}}, \overset{+}{\text{Net Inc.}}, \overset{-}{\text{Dividends}})$$

$$CE = f(\overset{+}{\text{Cash Flow}}, \overset{+}{\text{R \& D}}, \overset{+}{\text{New Debt}}, \overset{-}{\text{Net Working Capital}})$$

$$DIV = f(\overset{+}{\text{Dividends}_{t-1}}, \overset{+}{\text{Net Inc.}}, \overset{-}{\text{New Debt}})$$

$$\begin{matrix}EXT \\ FIN\end{matrix} = f(\overset{+}{\text{Cap. Exp.}}, \overset{-}{\text{Cash Flow}}, \overset{-}{\text{Dividends}})$$

Metrics in Industry Today

- Project management Metrics are advanced
  - NPD application dominates
  - Cycle time/time to market metrics common for NPD
  - Parameters differ across industries and business segments
- Portfolio Management metrics less advanced
  - R&D structure differences add complexity
  - Technical maturity of business segments adds complexity
- Globalization adds complexity---squared!

Data Sources of a Tech Intelligence Pro

'Technology Intelligence at Air Products: Leveraging Analysis and Collection Techniques', Merrill Brenner, Manager, Business and Technology Analysis, SCIP, Vol. 8, No. 3, May-June, 2005.

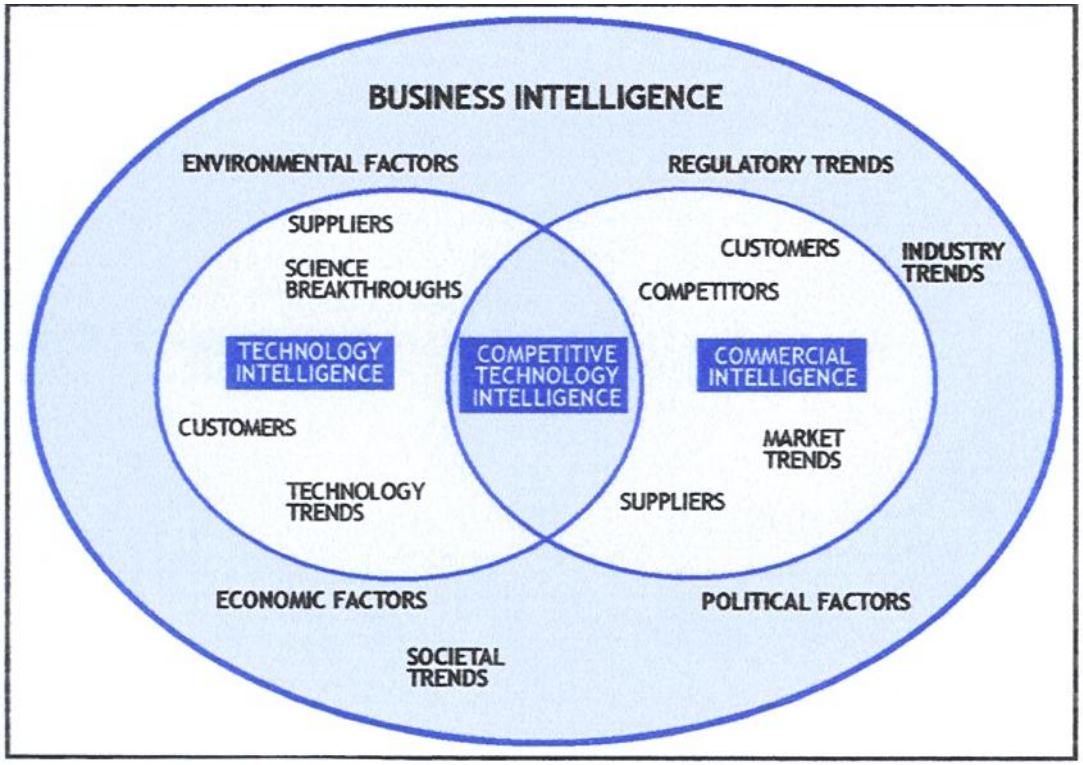
The following slides, prepared for the above article, are used with Merrill Brenner's permission.

- Fortune 500 Company
- $ 8 Billion in Annual Sales
- Operations in 30 Countries
- 20,000 employees globally
- HQ in Trexlertown , PA

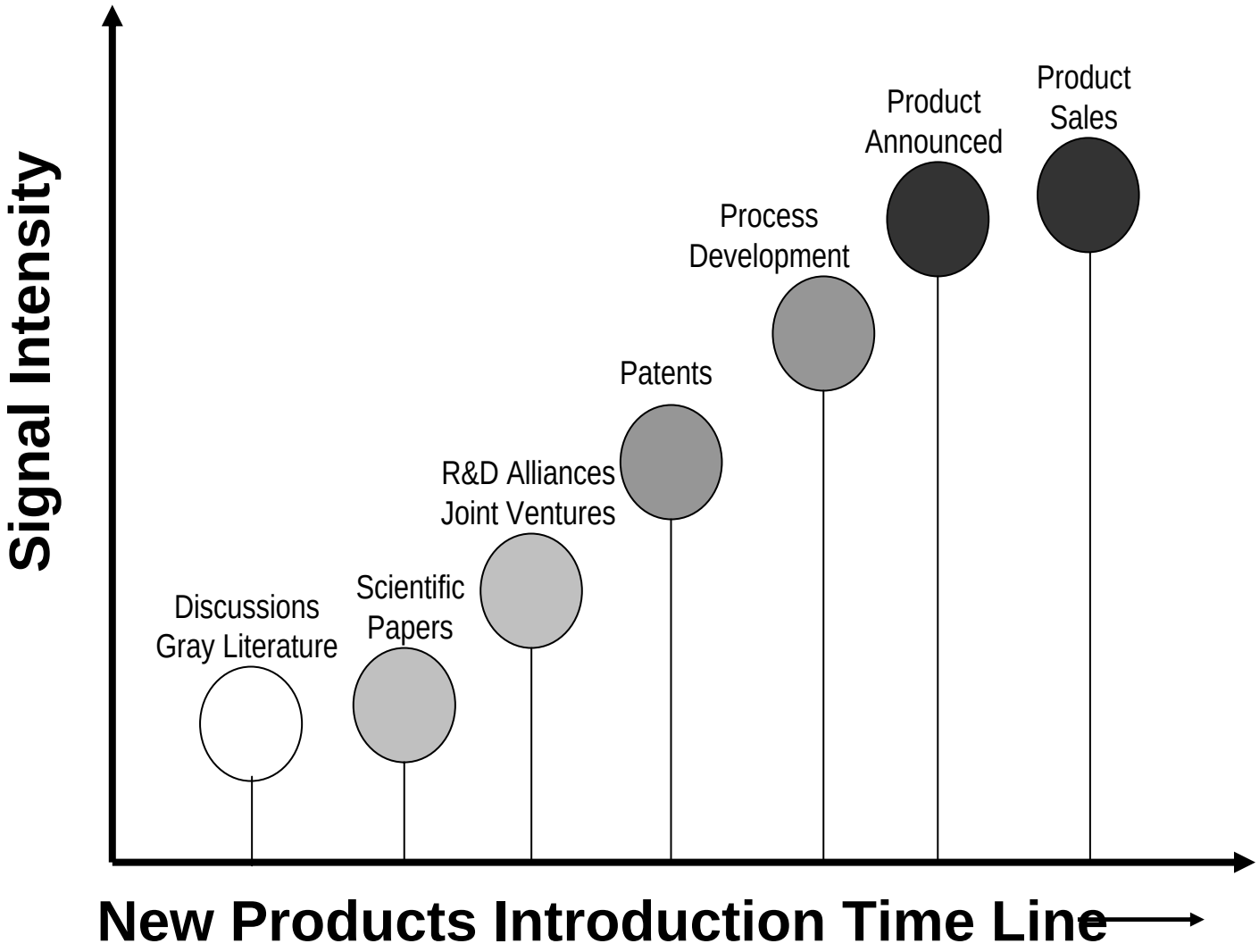
TABLE 1: AIR PRODUCTS

Products	Markets
Gases & equipment:	Adhesives and sealants
Cryogenic air separation of oxygen, nitrogen, argon	Aerospace
Hydrogen	Agriculture
Electronics gases, chemicals and services	Air pollution
Helium	Automotive
Specialty gases	Building and construction
Air separation equipment and technology, non-cryogenic air separation, LNG heat exchangers	Chemicals and refining
Homecare services	Electronics
Chemicals:	Energy
Emulsion polymers	Food
Amines	Furniture
Epoxy additives	Glass
Surfactants	Healthcare
Polyurethane intermediates	Metals
Polyurethane additives	Nonwovens
	Oil and gas production
	Paints and coatings
	Power generation
	Pulp and paper
	Rubber and plastics
	Textiles

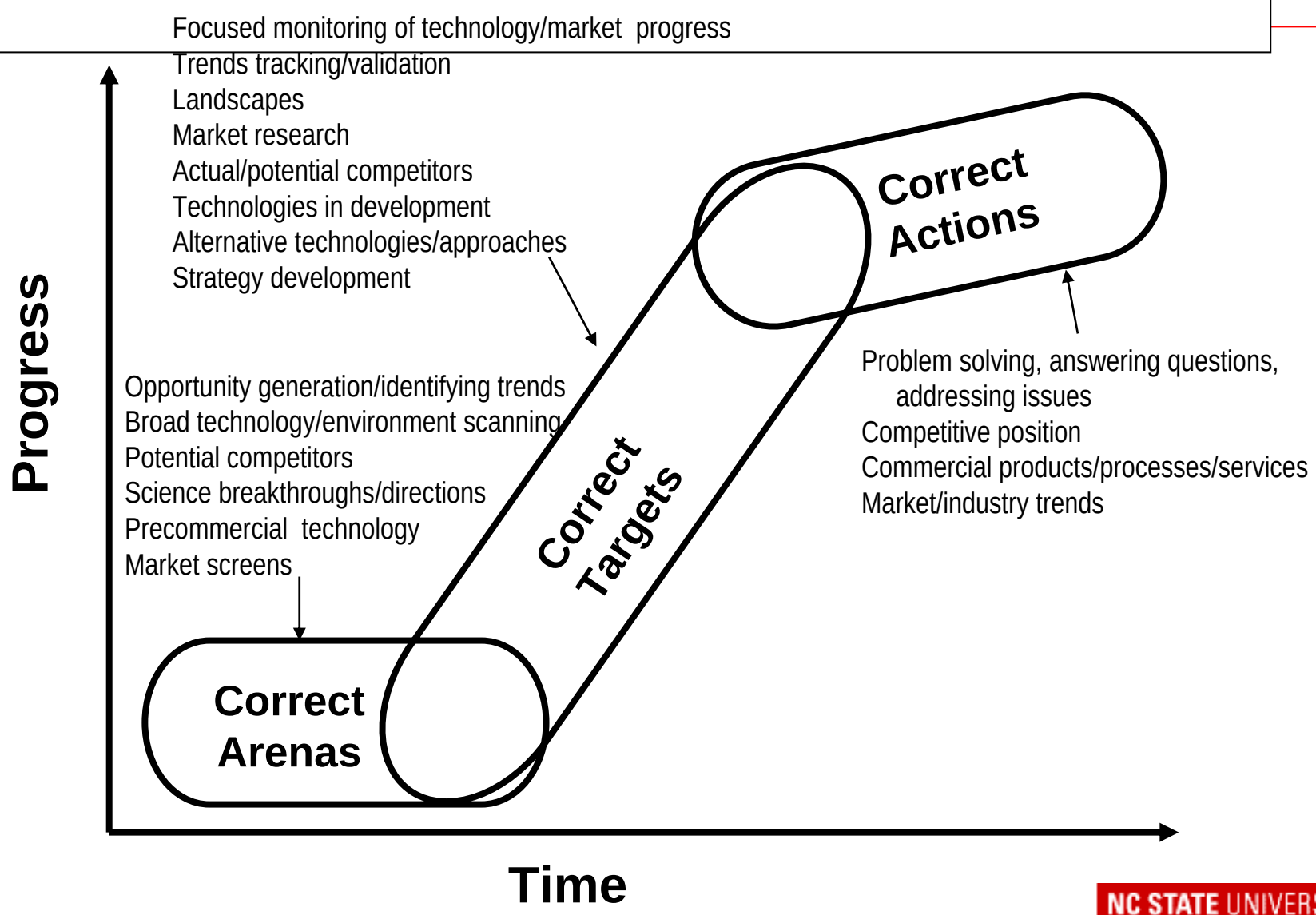
- Merrill Brenner's World



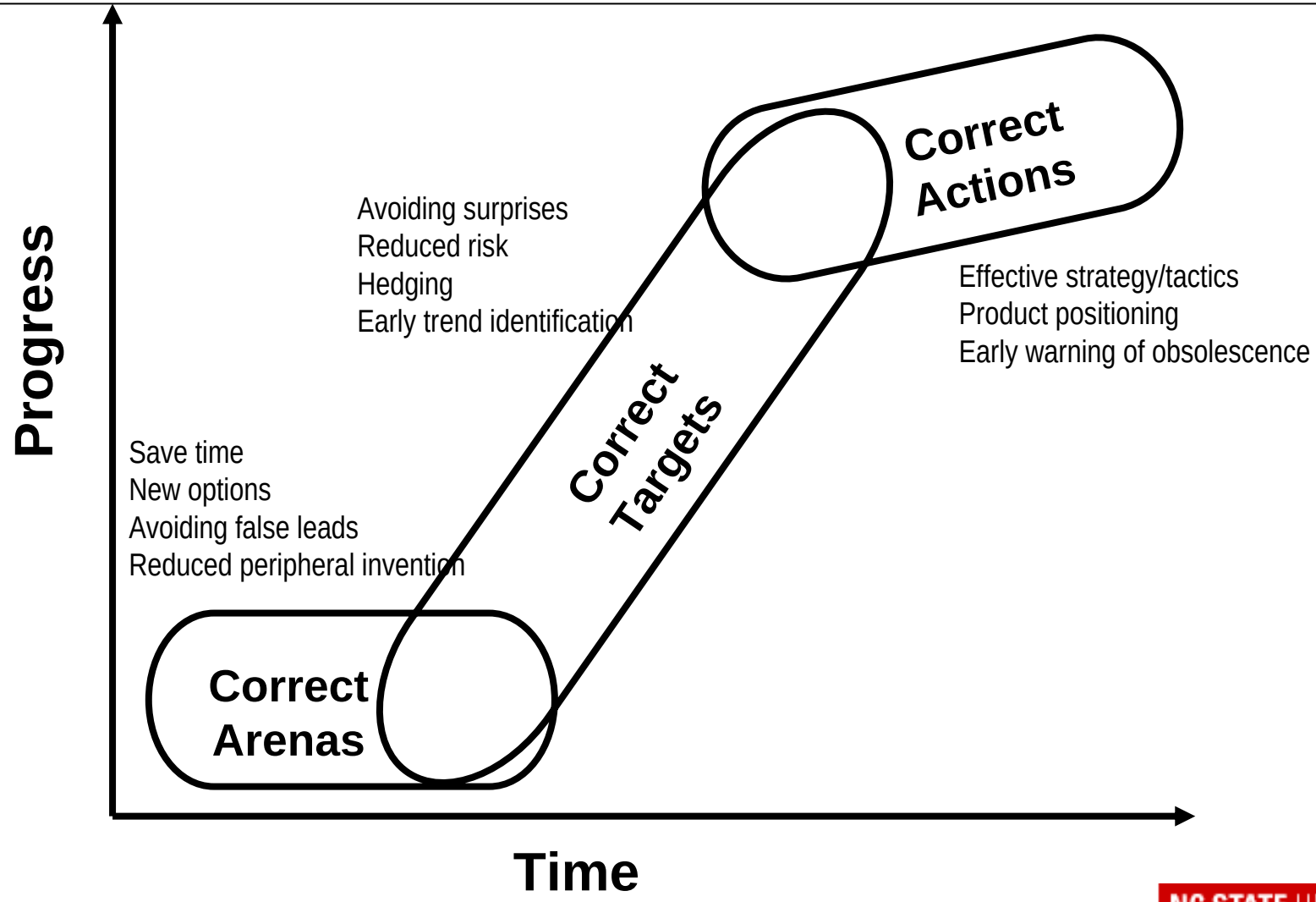
Technology Signals



Intelligence Focus



Intelligence Benefits



Closing Observations

- Industry today seeks ‘fresh’ data for strategic decision-making, measured in hours & days rather than years.
- The internet, trends in digitization, and tools like Google and data mining software are changing the innovation management information game
- Interesting to ponder what the minimal data set would contain in order to produce the most valuable set of direct and computed innovation management metrics for public & private stakeholders
- Companies are slowly becoming more sophisticated about internal metrics. Some can even compute Internal Rates of Return on individual NPD projects based on actual data they began collecting 15 years ago.