Systems Thinking Assessment of Multidiscipline Teams at NASA Langley Research Center

with Implications for their Formation, Management, and Operation

(Internal Dynamics)

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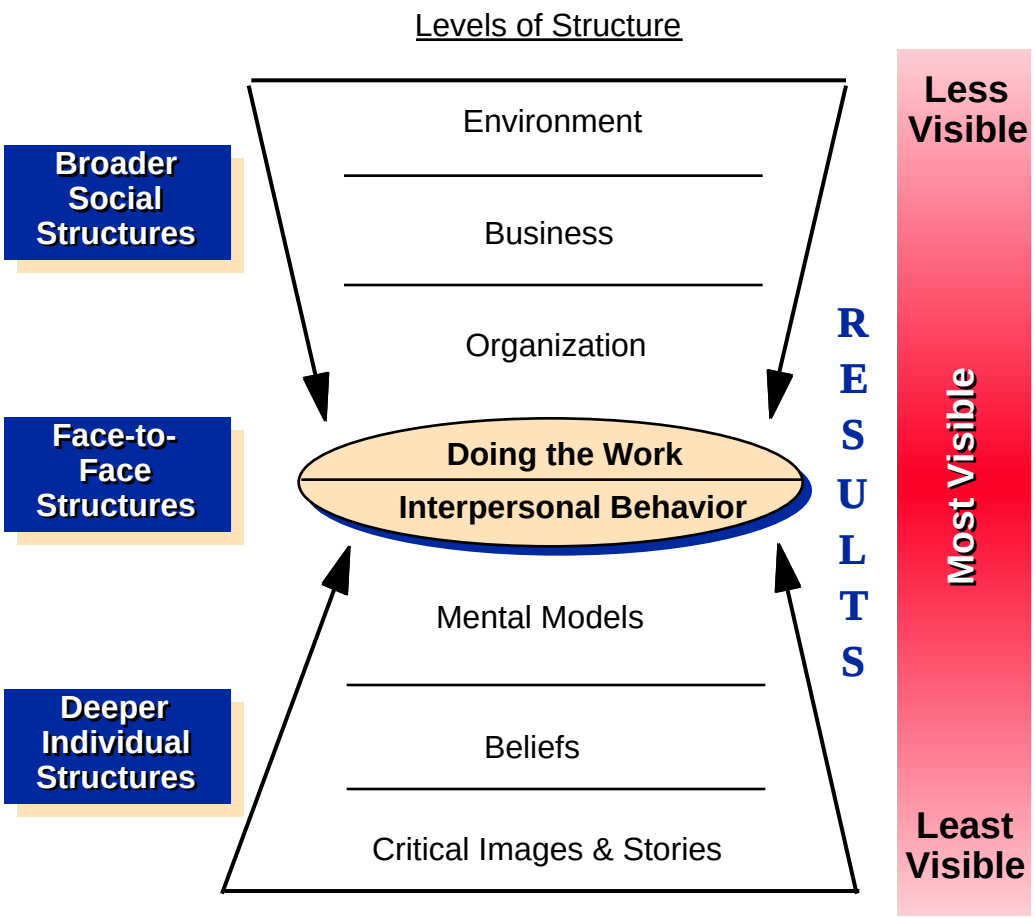
Key Objectives

- **Identify barriers to success for multidiscipline research teams at NASA Langley.**
- **Develop recommendations that will help multidiscipline teams to be more effective.**

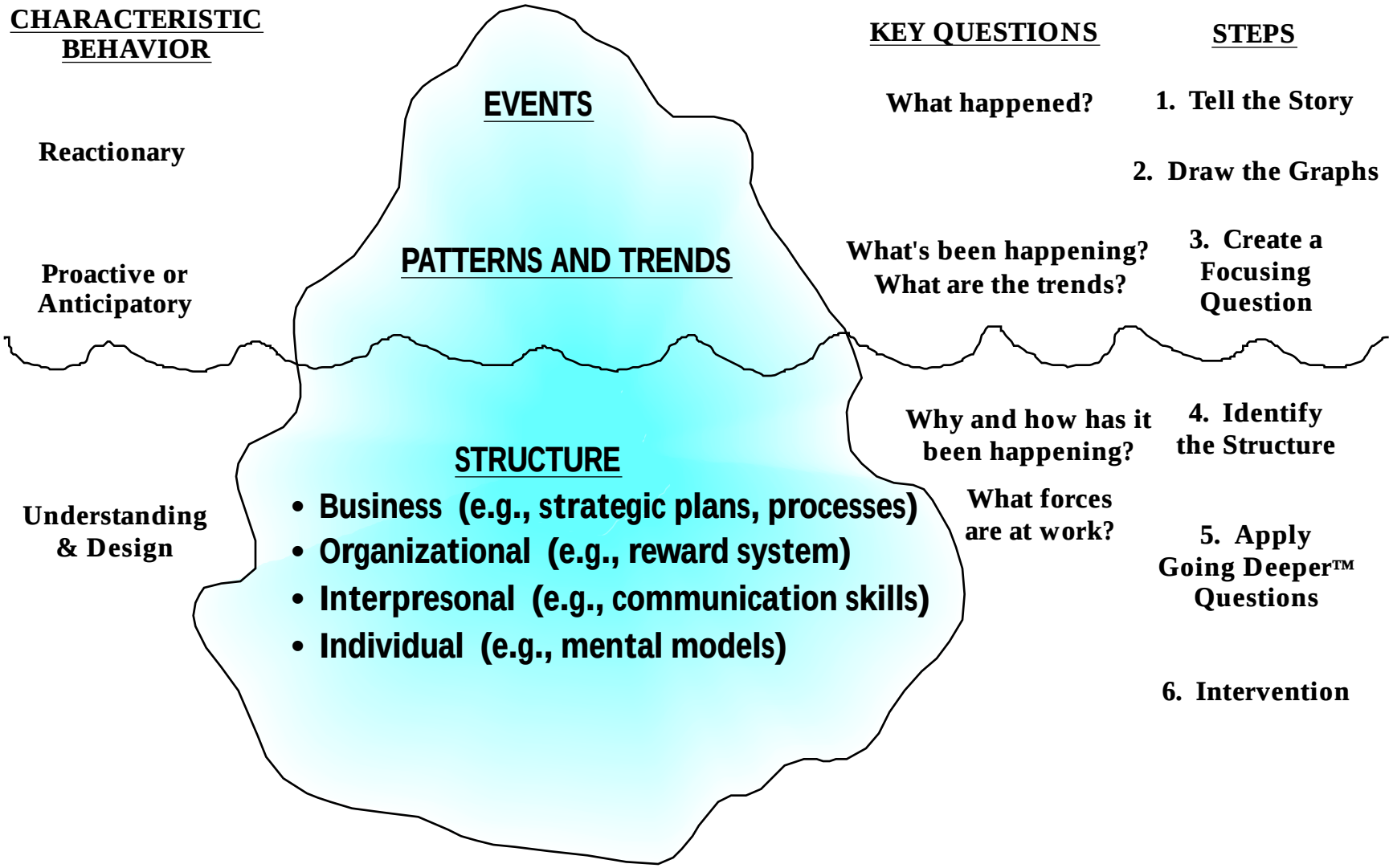
- *Develop a Langley-based application of systems thinking to a real, practical, and significant issue.*
- *Document the effort in a case study to be available for training and a reference for future efforts.*

Systems Thinking Overview

- **A discipline for seeing structures (the patterns and connections) underlying seemingly diverse personal, organizational and societal issues.**
- **Helps us understand and describe complex issues.**
- **Points to higher leverage solutions to problems.**
- **The harder you push, the harder the system pushes back.**
- **The easy way out usually leads back in.**
- **Small changes can produce big results -- but the areas of highest leverage are often the least obvious.**
- **There is no blame.**



Systems Thinking Framework



Our Approach

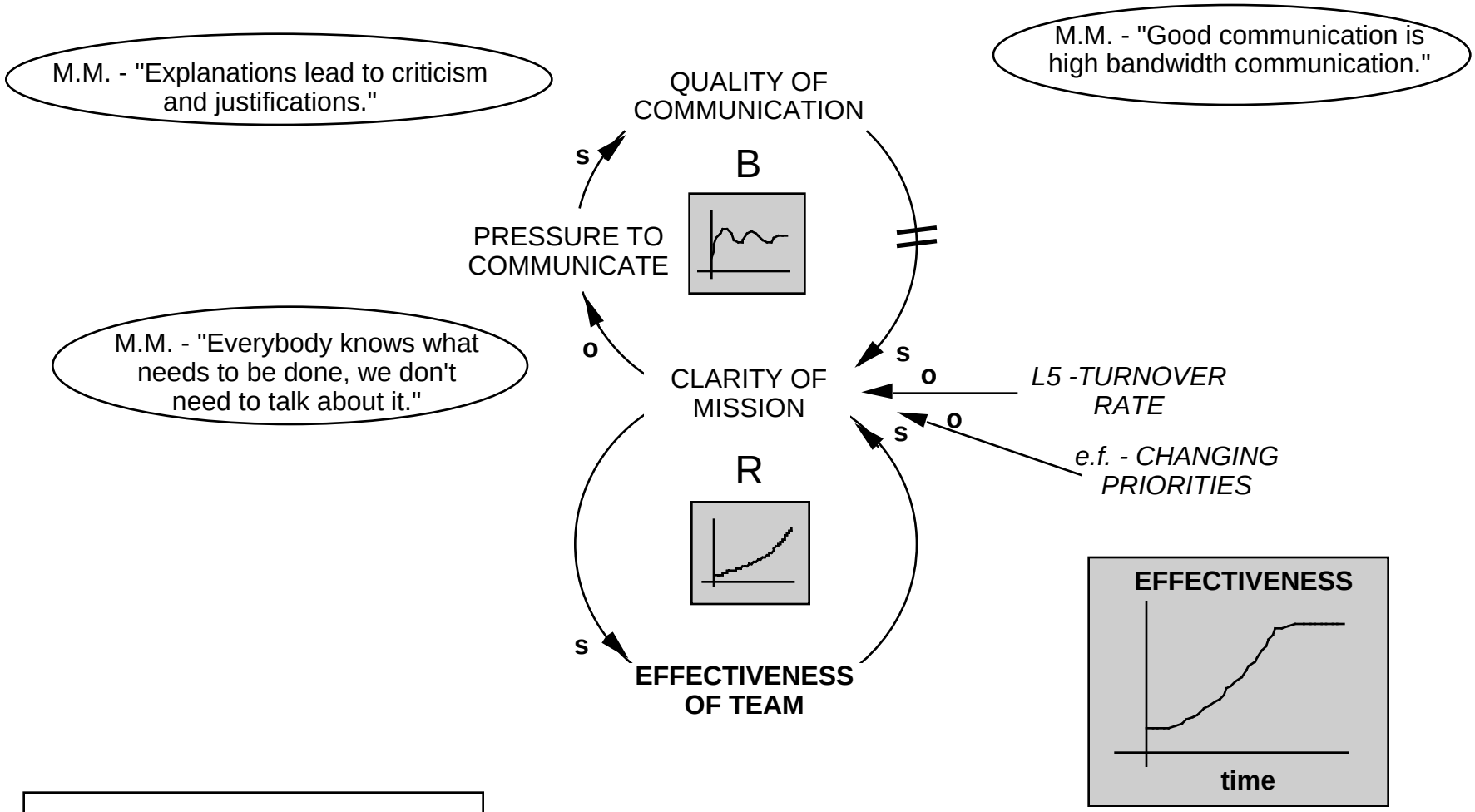
- **Select recent multidiscipline teams with a “rich” history**
  - **Airframe Noise Team (ANT)**
  - **Longitudinal Controls Alternatives Project (LCAP)**
  - **MDO Detailed Planning Team**
- **Interview cross-section of team members to determine influential factors affecting success**
- **Identify key variables and structural elements affecting team performance**
- **Distinguish between internal and external dynamics**
- **Seek causal relationships between key variables that supported the outcomes**
- **Diagram the causal links and identify archetypical structures that suggest potential interventions**
- **Identify high-leverage interventions to achieve desired results (long-lasting, self-sustaining, involving choice)**

Key Variables and Factors

- **The variable central to the key issue and to most of the causal links is *Team Effectiveness***
- **Represents a variety of *desired characteristics of highly successful teams***
  - **ability to meet milestones and deadlines**
  - **high quality products**
  - **long-term impact**
  - **exceed expectations (sponsor, organization, customers)**
  - **effective communication**
  - **high productivity and efficiency**
  - **. . .**

#1 - Clarity of Mission

Diagram



e.f. - External Factor
LX - Link to variable from Loop X.

Limits to Success Archetype

#1 - Clarity of Mission

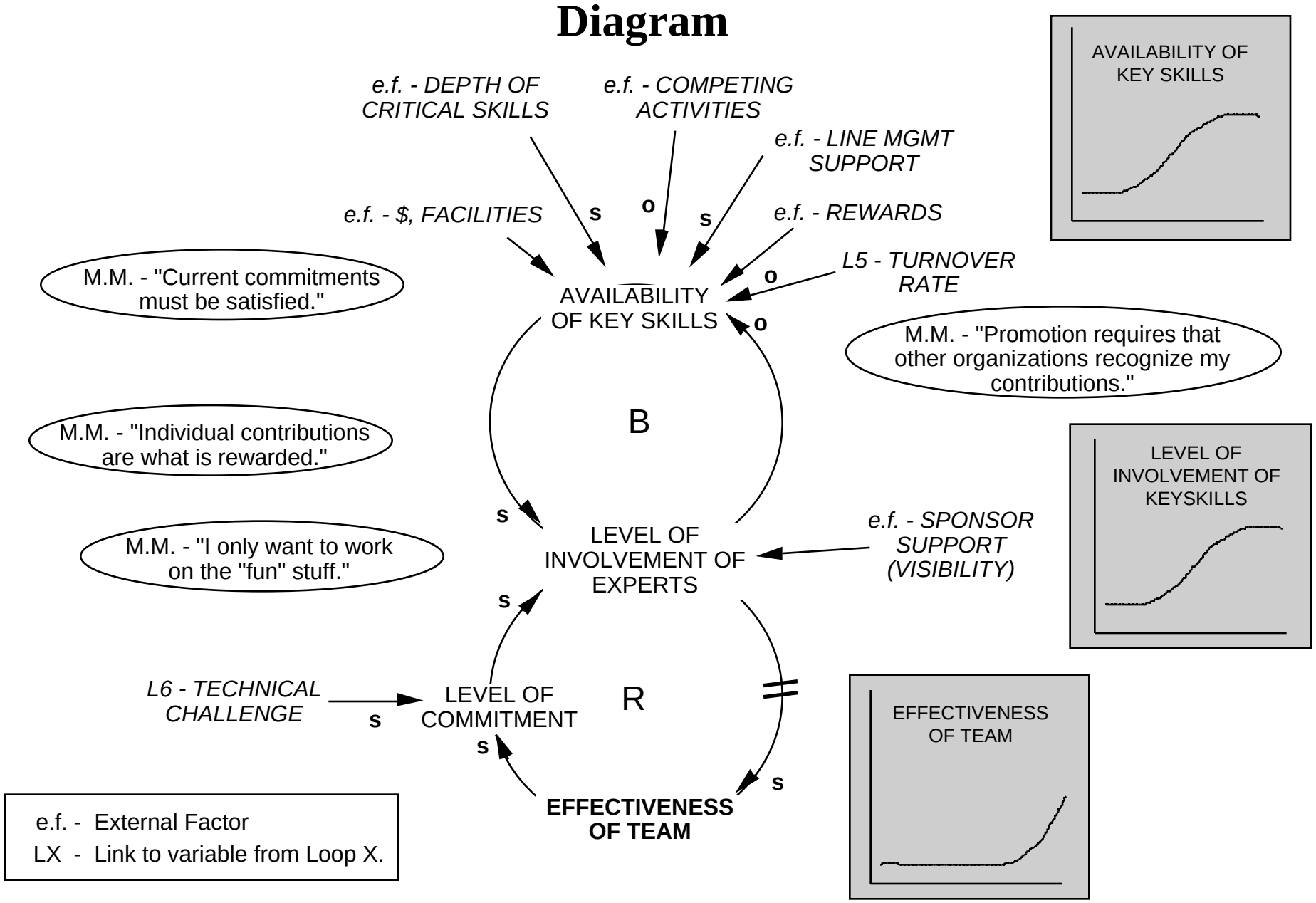
Key Structures and Interventions

- **Key Structures**
  - **a clear mission reduces pressure for communication**
  - **reduced communication erodes shared vision**
  - **everyone knows what needs to be done, we don't need to talk**
  - **open communication with significant inquiry can be seen as prying**
  - **high bandwidth is sometimes equated with good communication**

- **Potential Interventions**
  - **weaken link between pressure to communicate and quality of communication (keep the pressure on)**
    - **develop team processes to maintain focus on priorities and mission**
    - **adapt to changing needs of information content**
    - **monitor quality and quantity of communication**
    - **avoid trap of equating quality with quantity and/or frequency**

#2 - Involvement of Key Experts

Diagram



#2 - Involvement of Key Experts

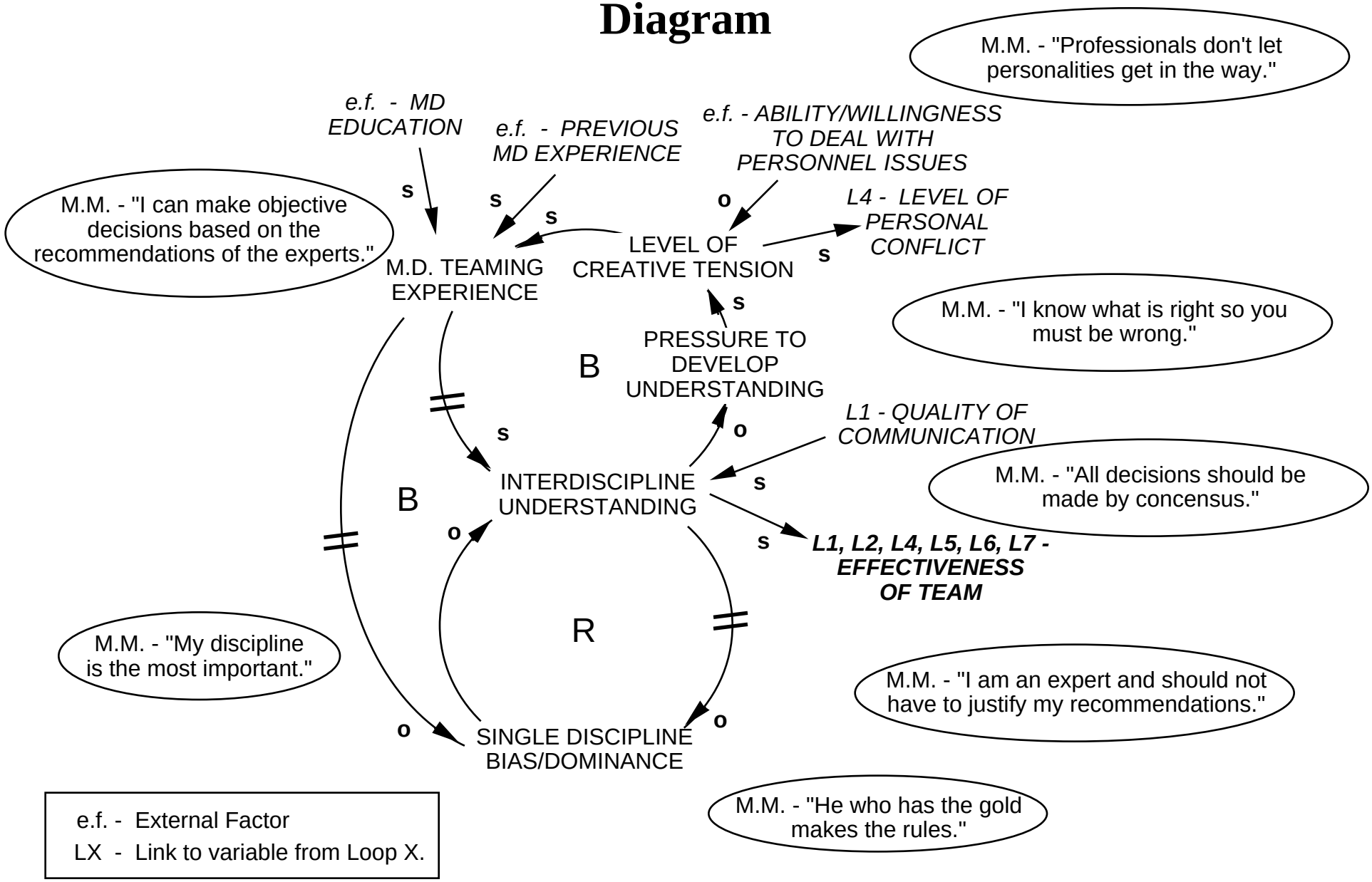
Key Structures and Interventions

- **Key Structures**
  - **improved effectiveness leads to more commitment and involvement of key experts**
  - **dependence on scarce resources puts pressure on key experts**
  - **fidelity to previous commitments**
  - **limited depth in certain key skills**
  - **individual contributions are what is recognized and rewarded**

- **Potential Interventions**
  - **increase availability of key skills**
    - **maintain and develop expertise in key areas**
    - **sacrifice short-term effectiveness for long-term benefit of enhanced skills and expertise ("on the job training")**
  - **enhance commitment of those with key skills**
    - **appeal to benefits of "stepping up"**
    - **strengthen "benefits" of team participation**

#3 - Multidisciplinary Teaming Experience

Diagram



#3 - Multidisciplinary Teaming Experience

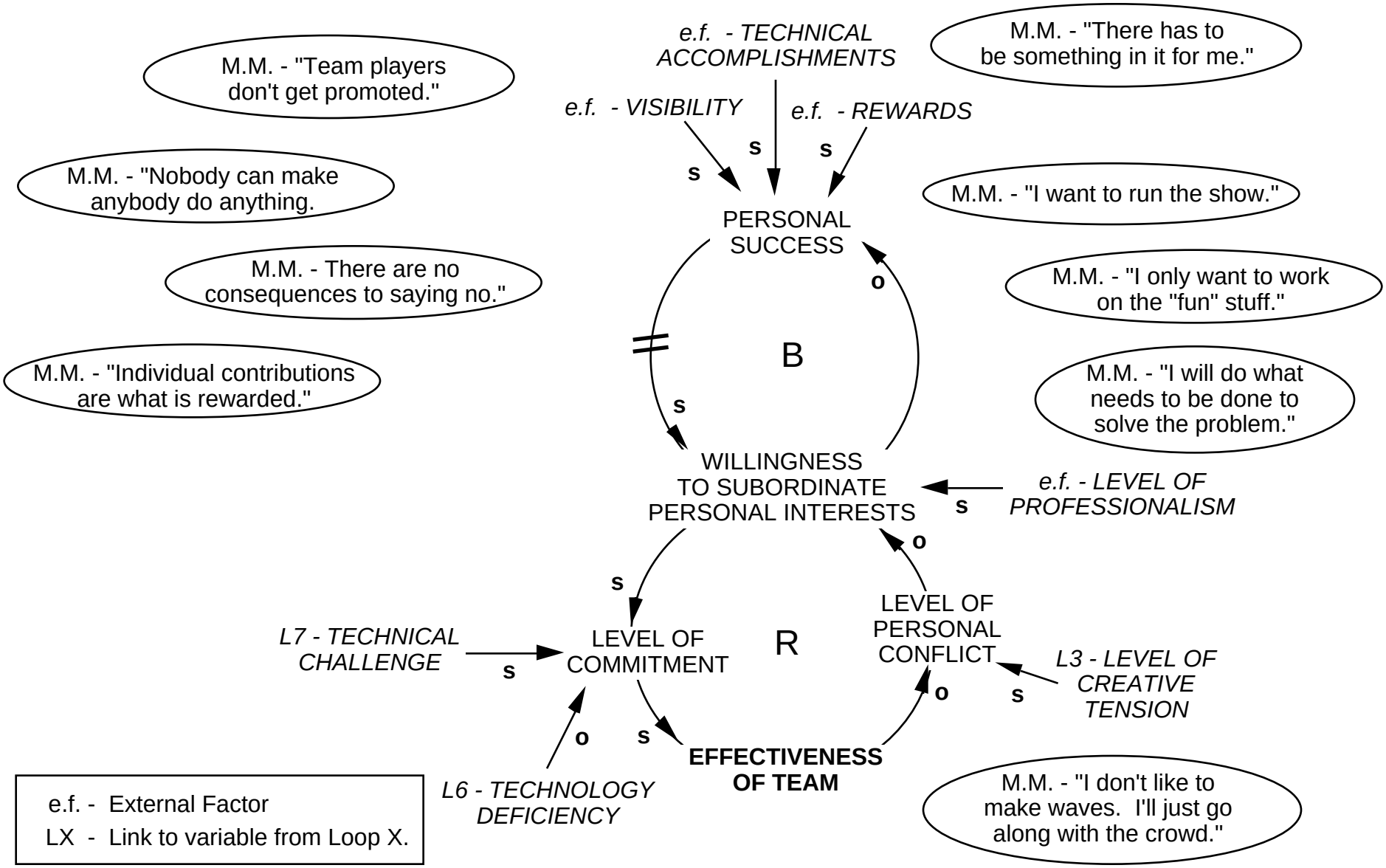
Key Structures and Interventions

- **Key Structures**
  - **creative tension is required to foster interdiscipline understanding**
  - **as understanding develops the pressure comes off**
  - **organizational bias toward single disciplines reinforces biases**
  - **tension can manifest itself as personal conflicts**

- **Potential Interventions**
  - **develop opportunities to enhance cross-discipline understanding and appreciation**
    - **increased number of multidiscipline efforts**
    - **expectation for skills development and educational opportunities**
  - **develop infrastructure to reduce tendency for single discipline focus**
    - **organizational and funding structures (e.g., ASPO)**
    - **program goals and objectives (e.g., 3 Pillars)**
  - **anticipate and deal promptly with conflicts that arise when working across organizations**

#4 - Willingness to be a Team Player

Diagram



#4 - Willingness to be a Team Player

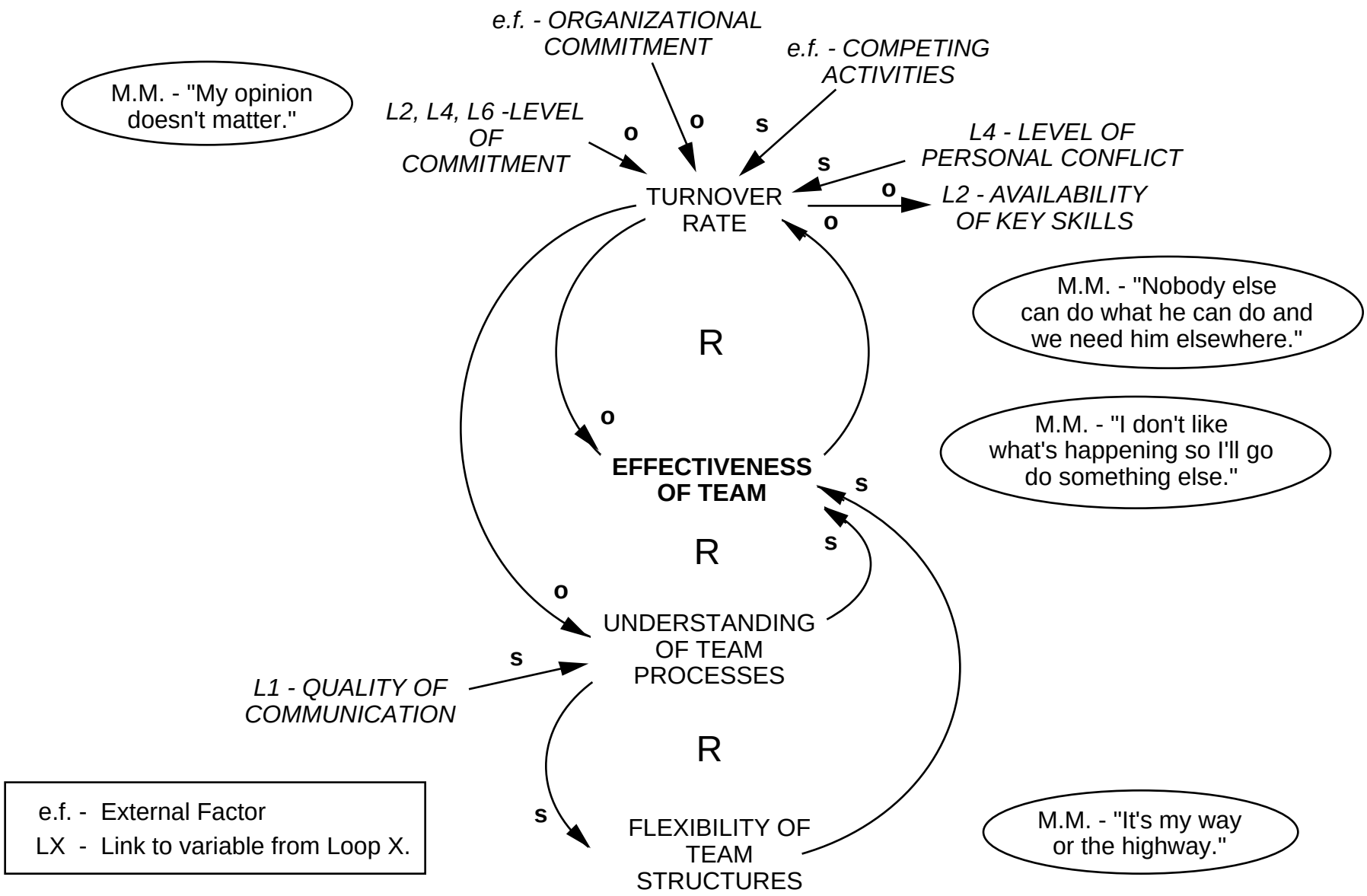
Key Structures and Interventions

- **Key Structures**
  - **multiplidisciplinary research often requires willingness to subordinate to team objectives**
  - **personal success has generally been associated with sophisticated discipline expertise and individual accomplishments**

- **Potential Interventions**
  - **link personal success to team success and team participation**
    - **strengthen structures that support desire to do multidiscipline work**
      - **rewards, visibility, technical challenges (goals and objectives)**
    - **emphasize personal benefits of team efforts**
      - **collaborative synergy, personal satisfaction, new knowledge / capability**
    - **weaken structures that support single discipline work**

#5 - Effectiveness of Team Processes

Diagram



#5 - Effectiveness of Team Processes

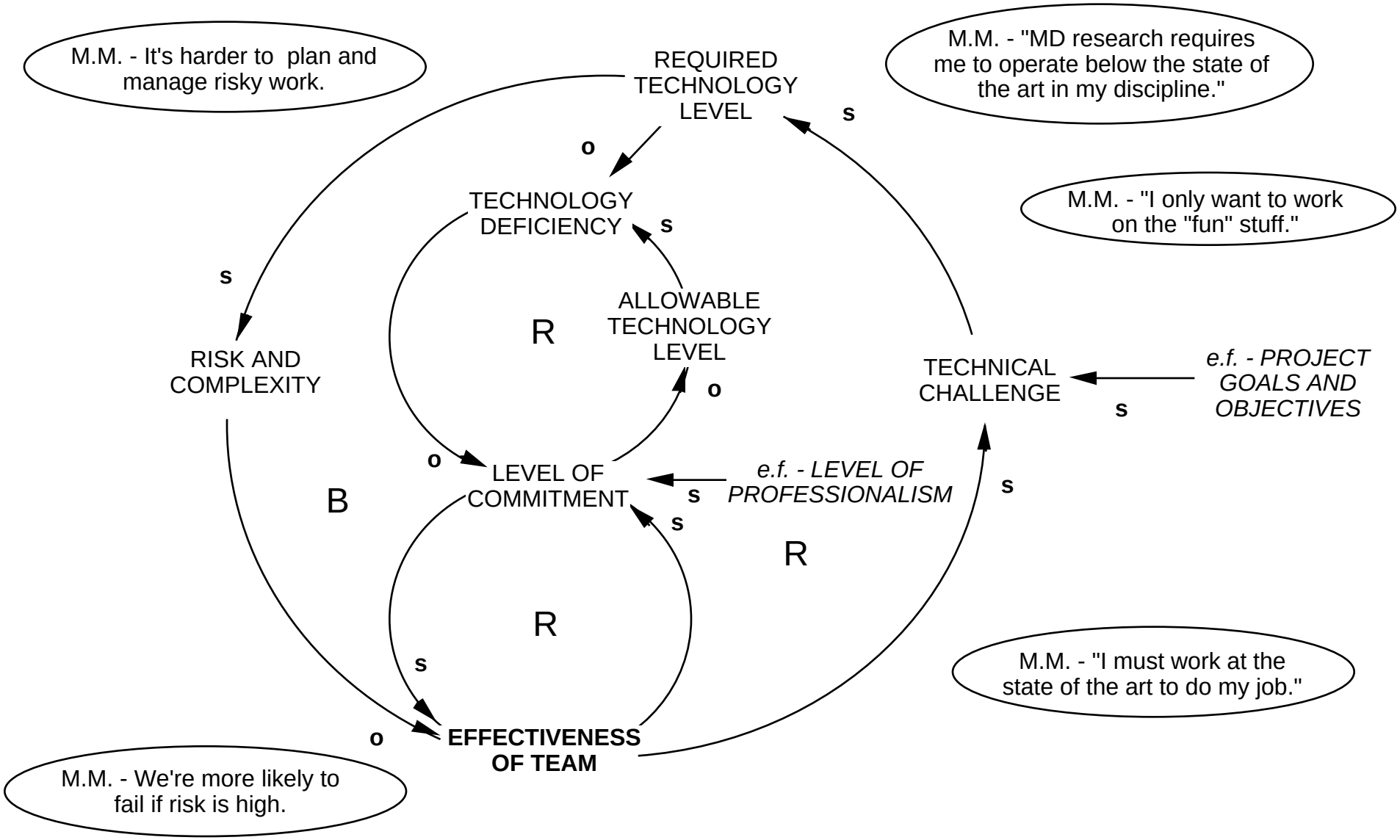
Key Structures and Interventions

- **Key Structures**
  - **effectiveness strongly dependent on turnover (loss is immediate, recovery is slow)**
    - **lost technical capability**
    - **backtracking, bringing new members up to speed**
  - **external factors play a major role (uncertainty, lack of control)**

- **Potential Interventions**
  - **minimize turnover in areas where expertise is key or scarce**
    - **match team members with project requirements**
    - **maintain sponsor support**
  - **anticipate and prepare for turnover in key areas**
    - **maintain flexible and adaptive team management processes to respond to changing priorities and concerns**
    - **utlilize benchmarks and guidelines for effective research team management methods (e.g., standards, common practices)**

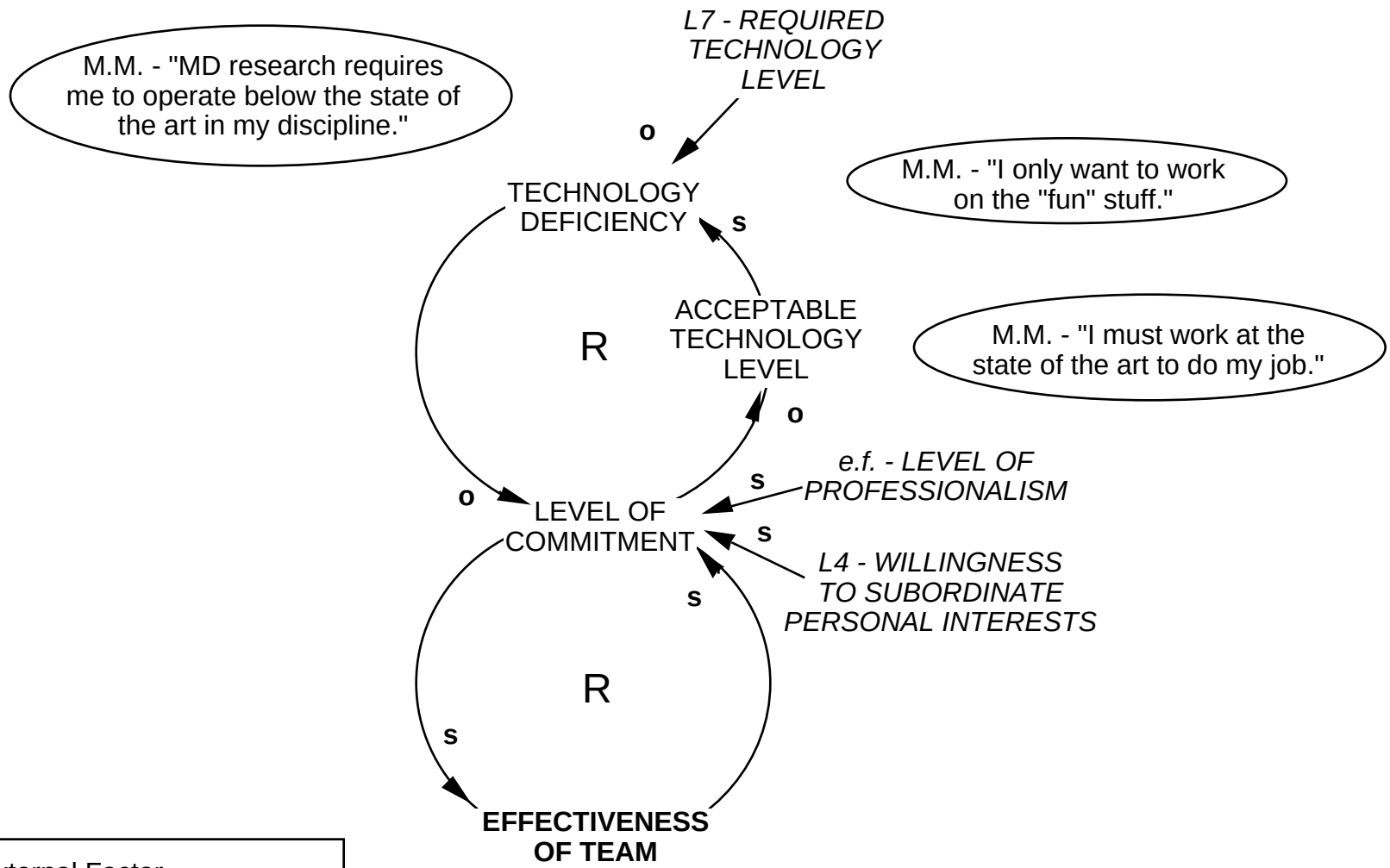
#6 + #7 - Balancing the Level of Technology

Diagram



#6 - Working Below the State of the Art

Diagram



e.f. - External Factor
LX - Link to variable from Loop X.

#6 - Working Below the State of the Art

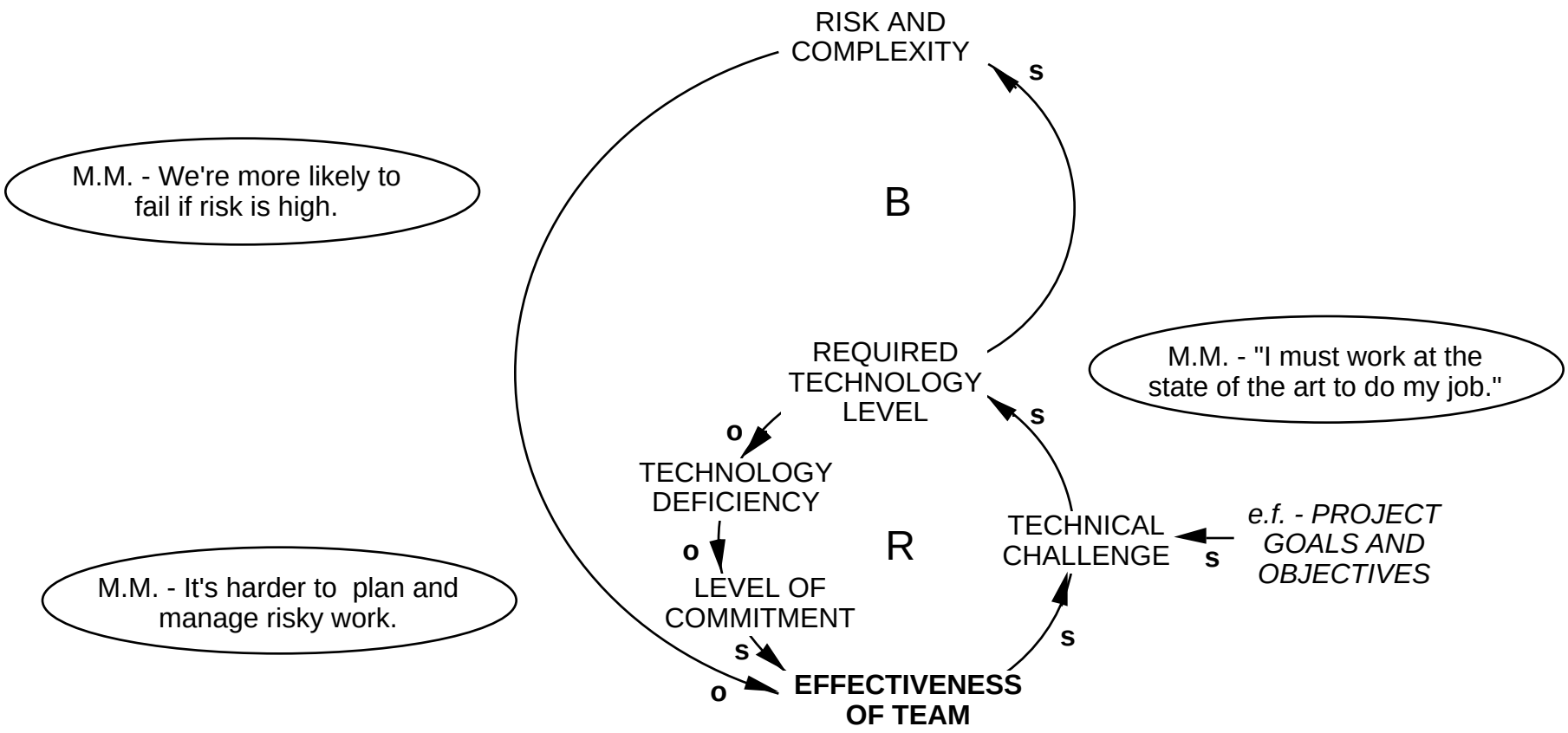
Key Structures and Interventions

- **Key Structures**
  - certain level of technology is required to achieve the objectives
  - certain level of technical sophistication is needed to interest and satisfy discipline researchers
  - difference between the two levels leads to erosion of commitment which exacerbates the problem (vicious circle)

- **Potential Interventions**
  - eliminate the technology deficiency
    - alter goals and objectives to increase the level of technology required
    - decrease the level of technical sophistication acceptable to individual researchers
  - enhance commitment by alternate means to deal with existing deficiency
  - select team members with tolerance for lower technical sophistication (match members with technologies)

#7 - Pushing the State of the Art

Diagram



e.f. - External Factor
LX - Link to variable from Loop X.

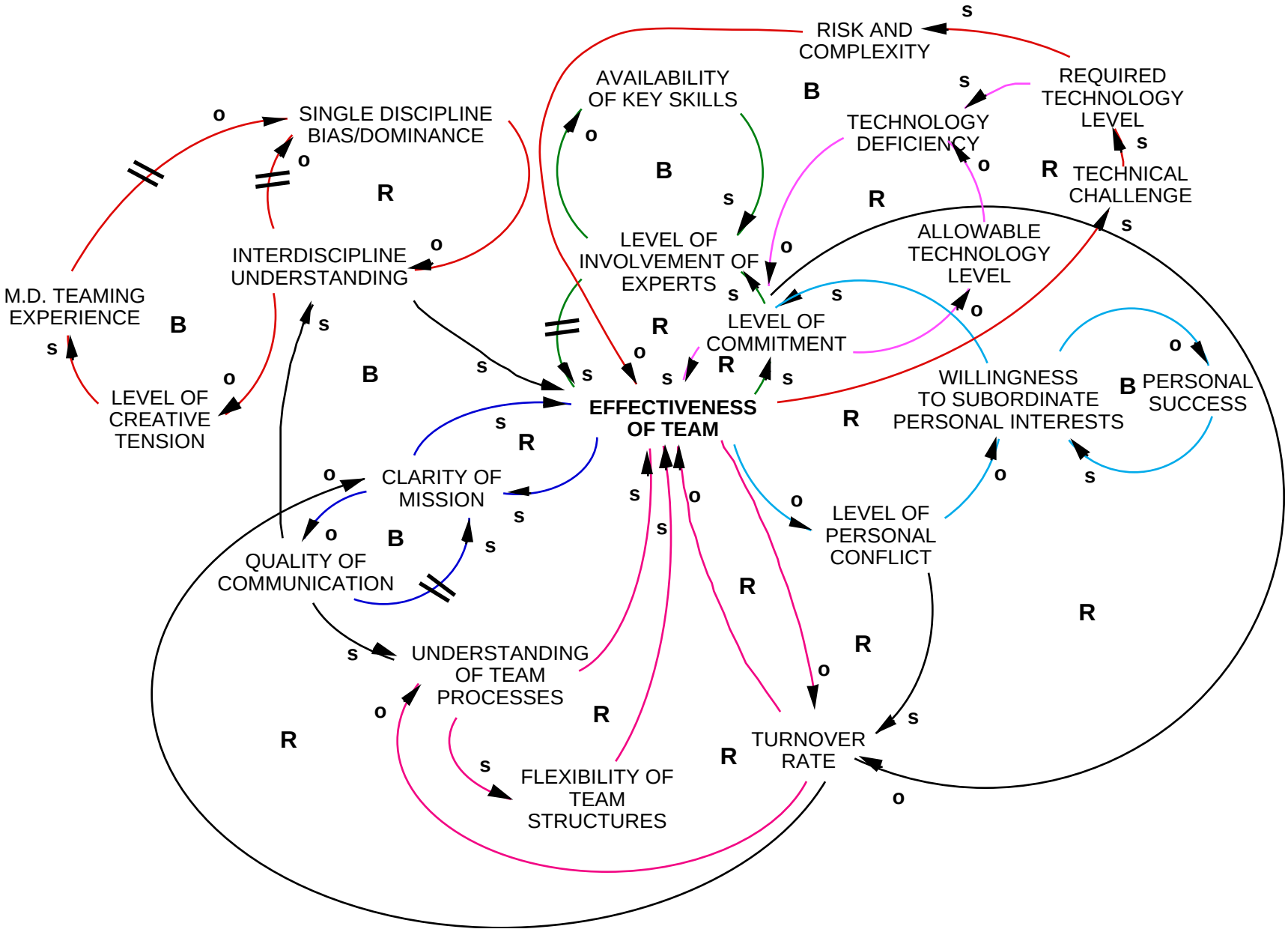
#7 - Pushing the State of the Art

Key Structures and Interventions

- **Key Structures**
  - **higher levels of technical challenge lead to the need for more sophisticated use of discipline technologies**
  - **team members motivated by applications of state of the art technologies in areas of expertise**
  - **higher level of sophistication leads to higher risk and complexity resulting in added difficulties which tend to reduce effectivness (schedule slips, blown budgets, etc.)**

- **Potential Interventions**
  - **accept added risk and complexity, plan for set-backs**
  - **set objectives to raise required technology level and allowable risk**
  - **develop experience/competence to reduce risk for given level of technology sophistication**

The Whole Story?



Guidance for Selecting Interventions

- **Look for interventions that**
  - **have impact throughout the system -- “work upstream”**
  - **are feasible and for which people are ready -- support is key!**

- **Culture and mental models are much harder to change than processes and procedures**

- **Implement changes in a logical sequence**
  - **don’t do everything at once**
  - **start small and build momentum slowly**
  - **be patient**

- **Be sensitive to time delays**
  - **delays in realization, understanding, design, implementation, impact**
  - **people typically underestimate delays by a factor of 3 to 5**

Desired Characteristics of Interventions

- **Highest Leverage Points (degree of influence throughout system)**
  - **Level of Commitment**
  - **Turnover Rate**
  - **Interdisciplinary Understanding**
  - **Quality of Communication**

- **Feasibility and Potential for Compliance**
  - **Leadership, Decisiveness**
  - **Enhanced freedom, control, and independence**
  - **Streamlining, Reduction in bureaucracy, reporting, oversight, etc.**
  - **Opportunities for reward and advancement**

- **Potential for Sustainable Change**
  - **Procedures, Processes**
  - **Produce creative tension**
  - **Limit conflict with established cultural values**

Summary of Recommended Interventions

Team Sponsors and Line Management

- ***Build level of commitment for multidisciplinary activities***
  - **emphasize and strengthen benefits of team participation**
  - **establish challenging individual objectives/goals within a multidisciplinary context**

- ***Enhance opportunities for cross-discipline understanding and appreciation***
  - **establish technical objectives that encourage discipline interactions**
  - **accept added risk and complexity, plan for set-backs**

- **Maintain and develop expertise in key areas**
  - **sacrifice short term effectiveness for long term benefit of enhancing skills and expertise**
  - **select team members with appropriate expertise for task**
  - **minimize turnover**

Summary of Recommended Interventions

Team Leaders and Team Management

- **Maintain flexible and adaptive team management processes**
  - **maintain focus on priorities and mission**
  - ***monitor quality of communications and adapt to changing needs of information content***
  - **develop and utilize benchmarks and guidelines for effective research team management methods**
  - **deal promptly with conflicts**

- ***Exploit and/or develop skills and expertise needed for multidiscipline research***
  - **accept added technical risk and complexity, plan for setbacks**
  - **match team members with technical requirements**
  - **develop key or scarce expertise for future needs**
  - **anticipate and prepare for turnover**
  - **emphasize and enhance benefits of team participation**

Summary of Recommended Interventions

Team Members

- ***Exploit benefits of multidiscipline teaming***
  - **opportunities for advancement and technical achievement**
  - **develop new knowledge and skills**
  - **establish and pursue meaningful technical challenges**
  - **accept technical risk and complexity to meet technical challenges**

- **Influence team processes and procedures**
  - **establish and maintain flexible and adaptive team processes to respond to changing priorities**
  - ***establish team processes that enhance interdiscipline understanding and communication***
  - **adapt to changing needs of information content**
  - **anticipate and deal promptly with conflicts**

Concluding Remarks

- **Results are representative of the teams that were studied**
- **Results represent significant aspects of team dynamics**
- **Likely to be representative of most multidisciplinary (and disciplinary) teams**
- **Additional assessment of consequences of proposed interventions are needed**
  - **leverage**
  - **influence and control**
  - **unintended consequences**
  - **significant delays**
  - **resource needs**