Lecture 10:
Managing Risk

General ideas about Risk

Risk Management

- Identifying Risks
- Assessing Risks

Case Study:

- Mars Polar Lander

Risk Management

About Risk

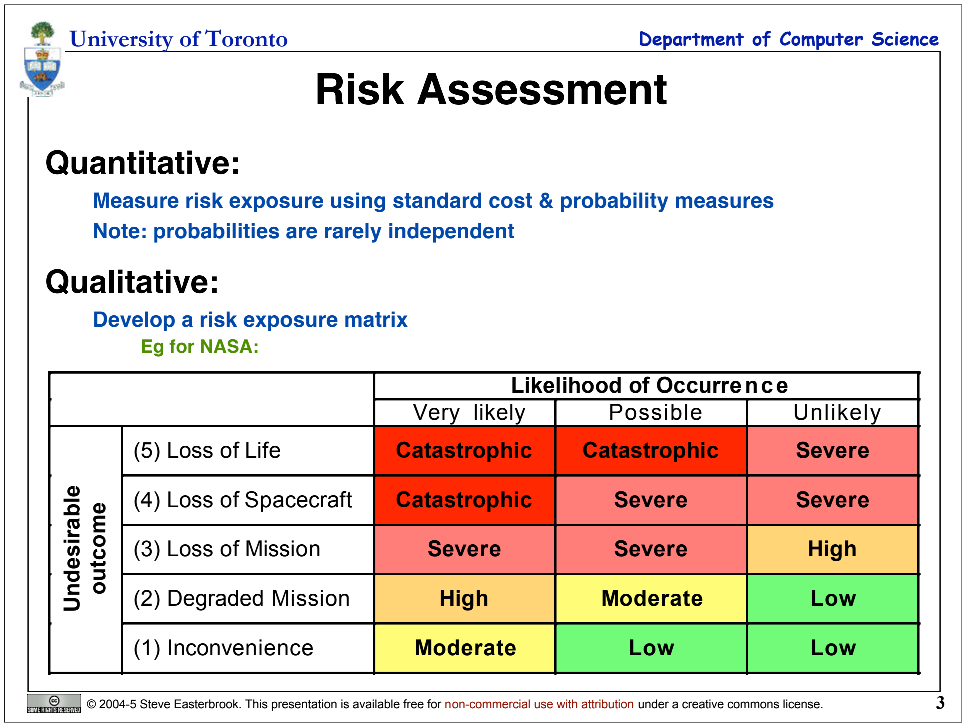
- Risk is “the possibility of suffering loss”
- Risk itself is not bad, it is essential to progress
- The challenge is to manage the amount of risk

Two Parts:

- Risk Assessment
- Risk Control

Useful concepts:

- For each risk: Risk Exposure
  - $RE = p(\text{unsat. outcome}) \times loss(\text{unsat. outcome})$
- For each mitigation action: Risk Reduction Leverage
  - $RRL = (RE_{before} - RE_{after}) / \text{cost of intervention}$



Risk Assessment

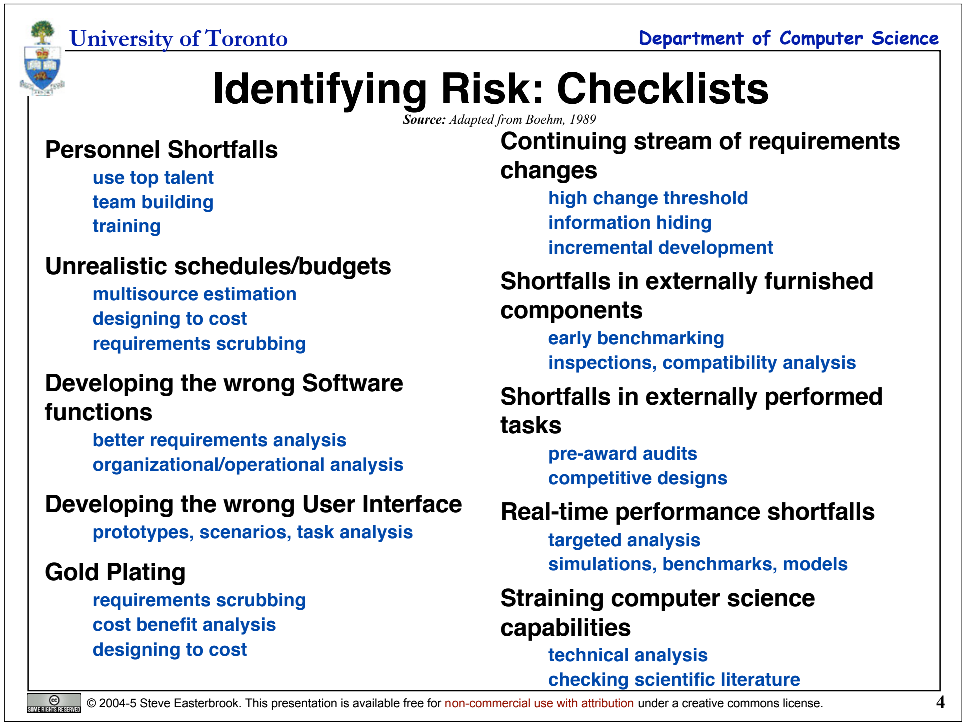
Quantitative:

- Measure risk exposure using standard cost & probability measures
- Note: probabilities are rarely independent

Qualitative:

- Develop a risk exposure matrix
  - Eg for NASA:

		Likelihood of Occurrence		
		Very likely	Possible	Unlikely
Undesirable outcome	(5) Loss of Life	Catastrophic	Catastrophic	Severe
	(4) Loss of Spacecraft	Catastrophic	Severe	Severe
	(3) Loss of Mission	Severe	Severe	High
	(2) Degraded Mission	High	Moderate	Low
	(1) Inconvenience	Moderate	Low	Low



Identifying Risk: Checklists

Source: *Adapted from Boehm, 1989*

Personnel Shortfalls
- use top talent
- team building
- training

Unrealistic schedules/budgets
- multisource estimation
- designing to cost
- requirements scrubbing

Developing the wrong Software functions
- better requirements analysis
- organizational/operational analysis

Developing the wrong User Interface
- prototypes, scenarios, task analysis

Gold Plating
- requirements scrubbing
- cost benefit analysis
- designing to cost

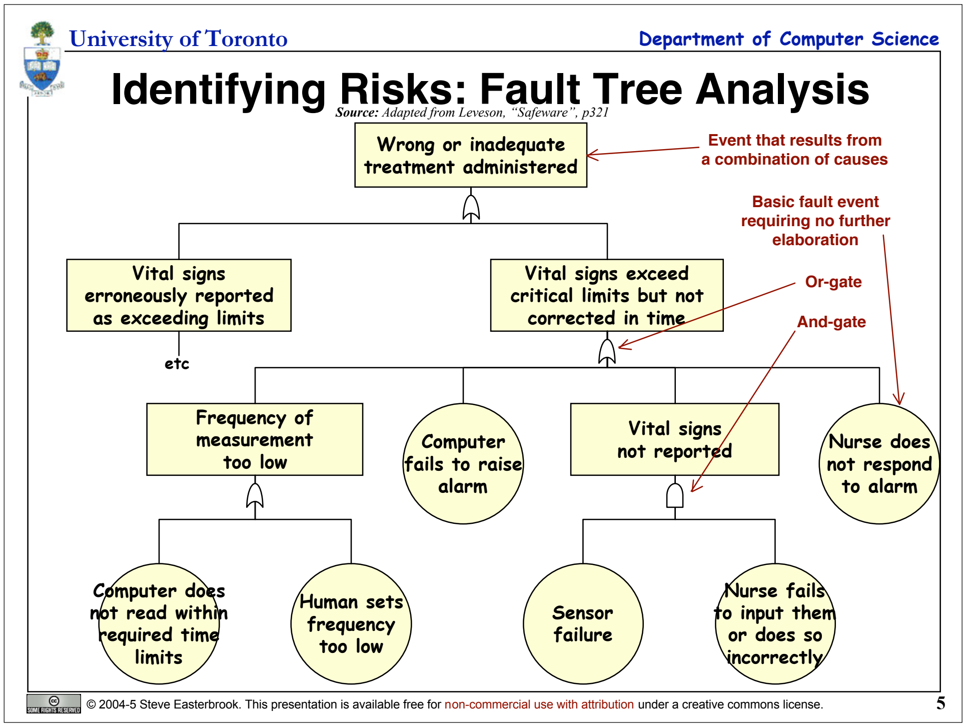
Continuing stream of requirements changes
- high change threshold
- information hiding
- incremental development

Shortfalls in externally furnished components
- early benchmarking
- inspections, compatibility analysis

Shortfalls in externally performed tasks
- pre-award audits
- competitive designs

Real-time performance shortfalls
- targeted analysis
- simulations, benchmarks, models

Straining computer science capabilities
- technical analysis
- checking scientific literature



Identifying Risks: Fault Tree Analysis

Source: *Adapted from Leveson, "Safeware", p321*

Wrong or inadequate treatment administered

Event that results from a combination of causes

Basic fault event requiring no further elaboration

Vital signs erroneously reported as exceeding limits

etc

Vital signs exceed critical limits but not corrected in time

Or-gate

And-gate

Frequency of measurement too low

Computer fails to raise alarm

Vital signs not reported

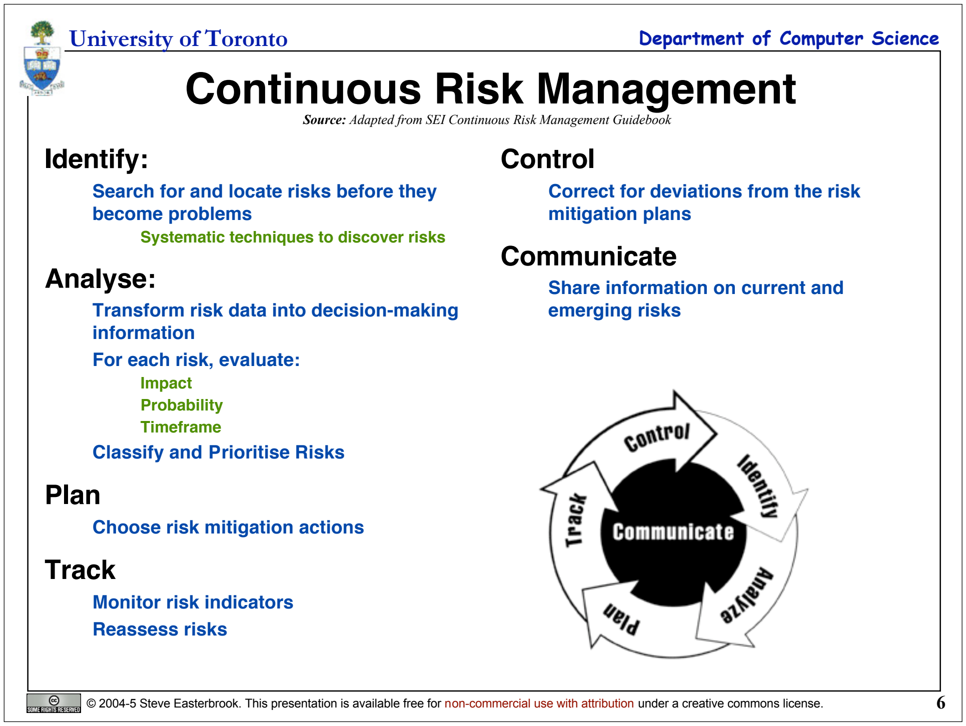
Nurse does not respond to alarm

Computer does not read within required time limits

Human sets frequency too low

Sensor failure

Nurse fails to input them or does so incorrectly



Continuous Risk Management

Source: *Adapted from SEI Continuous Risk Management Guidebook*

Identify:

- Search for and locate risks before they become problems
  - Systematic techniques to discover risks

Analyse:

- Transform risk data into decision-making information
- For each risk, evaluate:
  - Impact
  - Probability
  - Timeframe
- Classify and Prioritise Risks

Plan

- Choose risk mitigation actions

Track

- Monitor risk indicators
- Reassess risks

Control

- Correct for deviations from the risk mitigation plans

Communicate

- Share information on current and emerging risks

Control

Identify

Analyze

Plan

Track

Communicate

Principles of Risk Management

Source: *Adapted from SEI Continuous Risk Management Guidebook*

Global Perspective

- View software in context of a larger system
- For any opportunity, identify both:
  - Potential value
  - Potential impact of adverse results

Forward Looking View

- Anticipate possible outcomes
- Identify uncertainty
- Manage resources accordingly

Open Communications

- Free-flowing information at all project levels
- Value the individual voice
  - Unique knowledge and insights

Integrated Management

- Project management is risk management!

Continuous Process

- Continually identify and manage risks
- Maintain constant vigilance

Shared Product Vision

- Everybody understands the mission
  - Common purpose
  - Collective responsibility
  - Shared ownership
- Focus on results

Teamwork

- Work cooperatively to achieve the common goal
- Pool talent, skills and knowledge

Case Study: Mars Climate Orbiter

Launched

- 11 Dec 1998

Mission

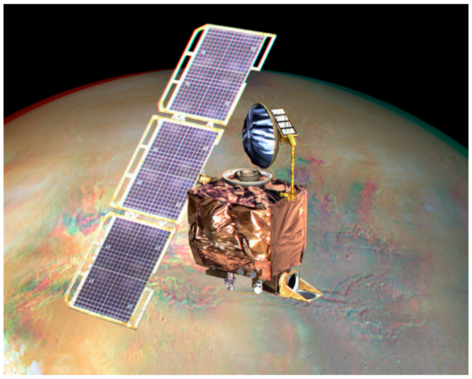
- interplanetary weather satellite
- communications relay for Mars Polar Lander

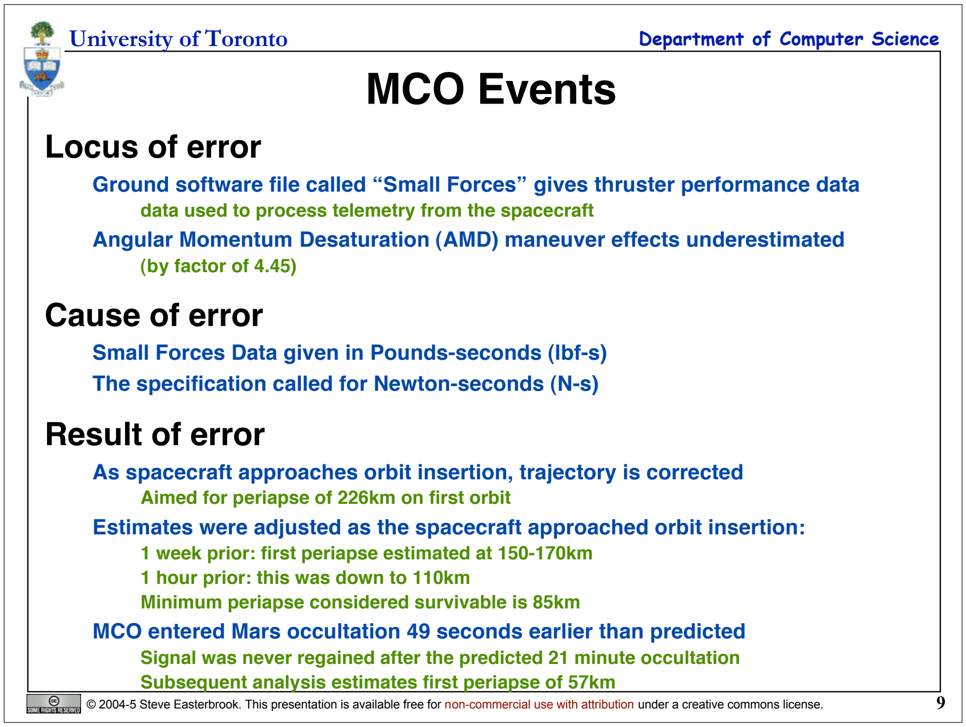
Fate:

- Arrived 23 Sept 1999
- No signal received after initial orbit insertion

Cause:

- Faulty navigation data caused by failure to convert imperial to metric units





MCO Events

Locus of error

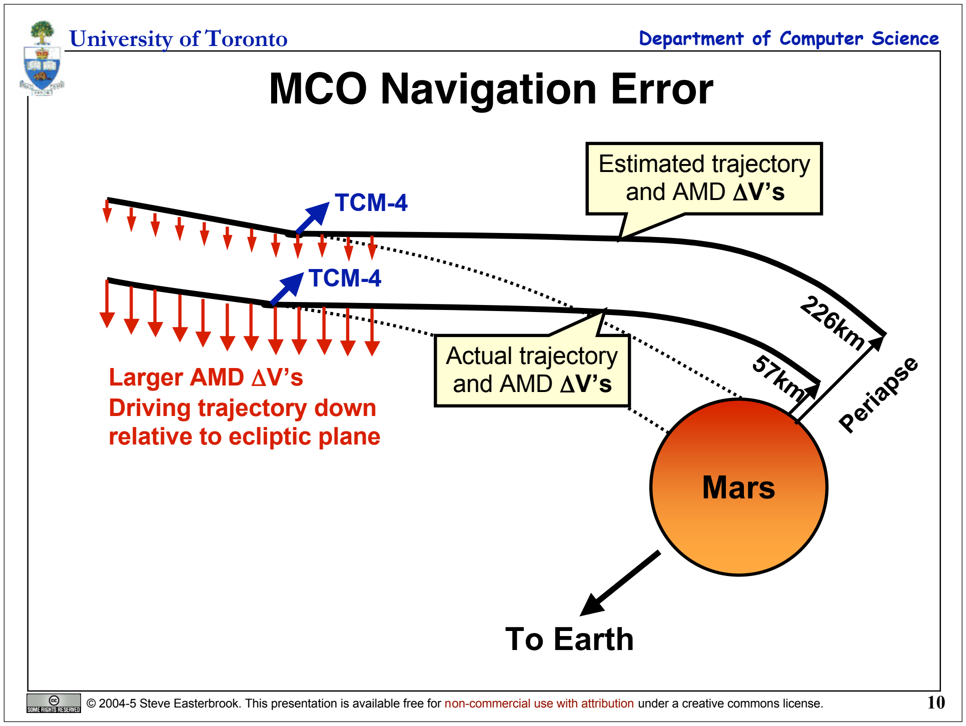
- Ground software file called “Small Forces” gives thruster performance data
  - data used to process telemetry from the spacecraft
- Angular Momentum Desaturation (AMD) maneuver effects underestimated
  - (by factor of 4.45)

Cause of error

- Small Forces Data given in Pounds-seconds (lbf-s)
- The specification called for Newton-seconds (N-s)

Result of error

- As spacecraft approaches orbit insertion, trajectory is corrected
  - Aimed for periapse of 226km on first orbit
- Estimates were adjusted as the spacecraft approached orbit insertion:
  - 1 week prior: first periapse estimated at 150-170km
  - 1 hour prior: this was down to 110km
  - Minimum periapse considered survivable is 85km
- MCO entered Mars occultation 49 seconds earlier than predicted
  - Signal was never regained after the predicted 21 minute occultation
  - Subsequent analysis estimates first periapse of 57km



MCO Navigation Error

Estimated trajectory and AMD ΔV’s
TCM-4
TCM-4
226km
57km
Periapse
Actual trajectory and AMD ΔV’s
Larger AMD ΔV’s Driving trajectory down relative to ecliptic plane
Mars
To Earth

Contributing Factors

For 4 months, AMD data not used (file format errors)

- Navigators calculated data by hand
- File format fixed by April 1999
- Anomalies in the computed trajectory became apparent almost immediately

Limited ability to investigate:

- Thrust effects measured along line of sight using doppler shift
- AMD thrusts are mainly perpendicular to line of sight

Poor communication

- Navigation team not involved in key design decisions
- Navigation team did not report the anomalies in the issue tracking system

Inadequate staffing

- Operations team monitoring 3 missions simultaneously (MGS, MCO and MPL)

Operations Navigation team unfamiliar with spacecraft

- Different team from development & test
- Did not fully understand significance of the anomalies
- Surprised that AMD was performed 10-14 times more than expected

Inadequate Testing

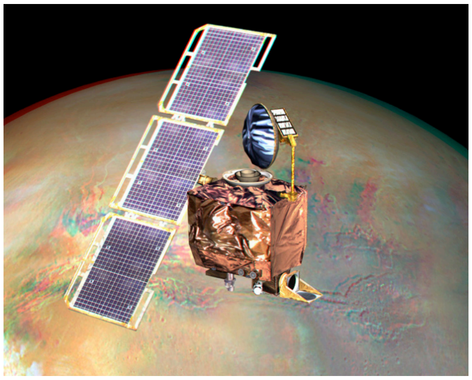
- Software Interface Spec not used during unit test of small forces software
- End-to-end test of ground software was never completed
- Ground software considered less critical

Inadequate Reviews

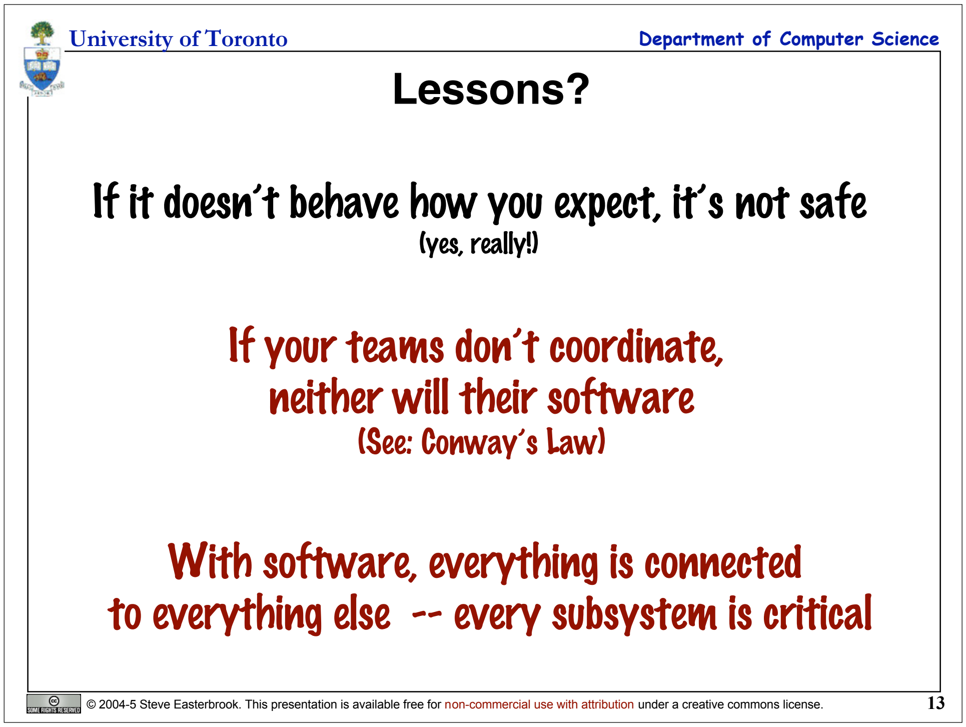
- Key personnel missing from critical design reviews

Inadquate margins…

Mars Climate Orbiter



Mars Global Surveyor

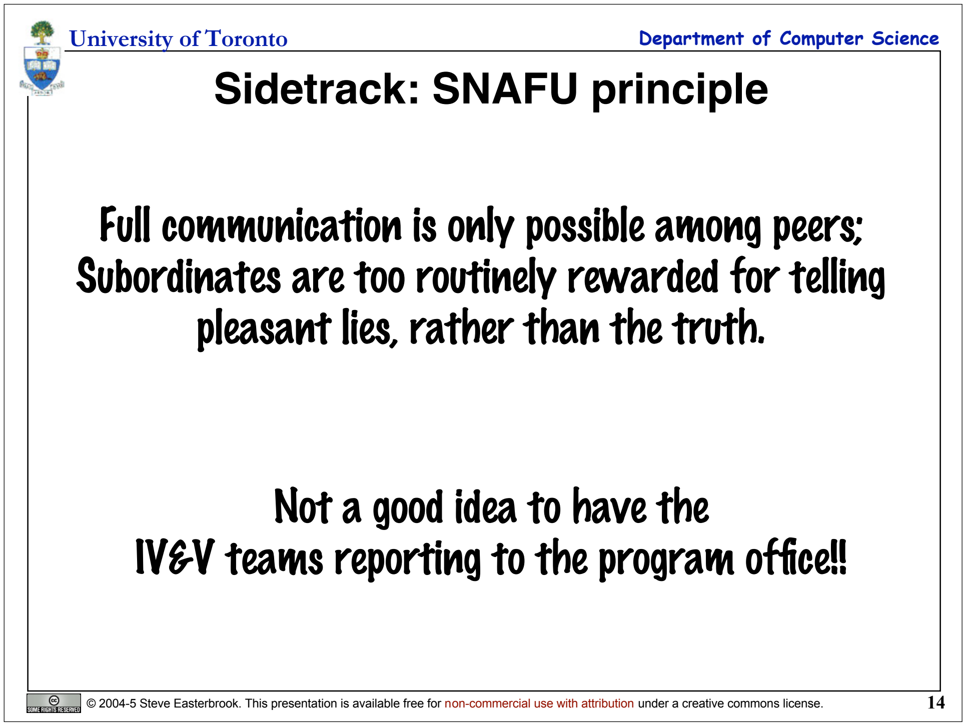


Lessons?

If it doesn't behave how you expect, it's not safe
(yes, really!)

If your teams don't coordinate,
neither will their software
(See: Conway's Law)

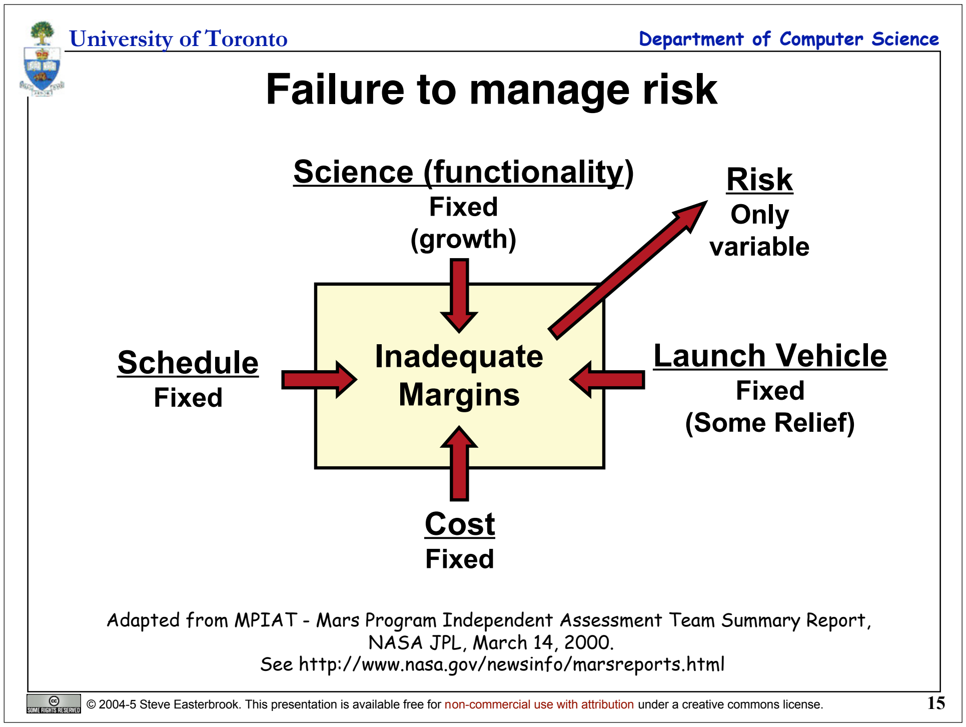
With software, everything is connected
to everything else -- every subsystem is critical



Sidetrack: SNAFU principle

Full communication is only possible among peers;
Subordinates are too routinely rewarded for telling
pleasant lies, rather than the truth.

Not a good idea to have the
IV&V teams reporting to the program office!!



Failure to manage risk

Science (functionality)
Fixed
(growth)

Risk
Only
variable

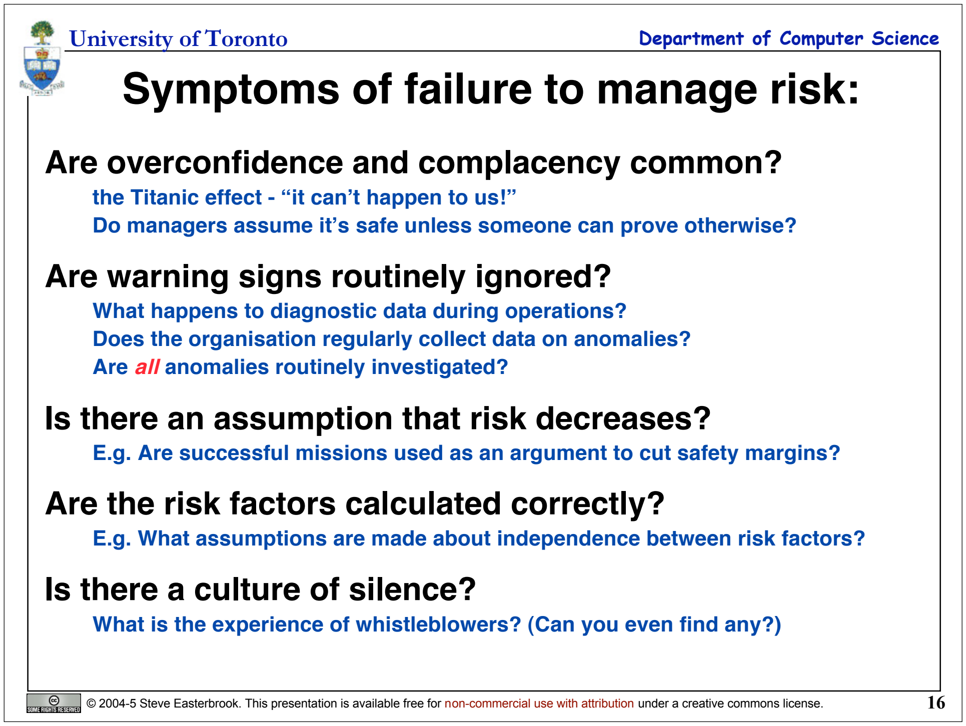
Schedule
Fixed

Inadequate Margins

Launch Vehicle
Fixed
(Some Relief)

Cost
Fixed

Adapted from MPIAT - Mars Program Independent Assessment Team Summary Report,
NASA JPL, March 14, 2000.
See http://www.nasa.gov/newsinfo/marsreports.html



Symptoms of failure to manage risk:

Are overconfidence and complacency common?

- the Titanic effect - "it can't happen to us!"
- Do managers assume it's safe unless someone can prove otherwise?

Are warning signs routinely ignored?

- What happens to diagnostic data during operations?
- Does the organisation regularly collect data on anomalies?
- Are *all* anomalies routinely investigated?

Is there an assumption that risk decreases?

- E.g. Are successful missions used as an argument to cut safety margins?

Are the risk factors calculated correctly?

- E.g. What assumptions are made about independence between risk factors?

Is there a culture of silence?

- What is the experience of whistleblowers? (Can you even find any?)