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# The influence of mental workload in causes of system degradation in air traffic control

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# Agenda

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- Aims
- Method
- Results
  - Causes of degradation: the relationship with workload
  - Relationships between causes
  - Prevention and mitigation of degradation – the ATCO role
  - Towards a theory of a system performance envelope
- Conclusions & Implications

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# Research motivation

- New initiatives (Nextgen, SESAR) call for reduced flexibility and increased precision and efficiency
- In order for the TBO concept to be realized, there will be a “fundamental shift in ATM” (FAA, 2014):
  - Narrower tolerances (FAA, 2014)
  - More precise trajectories
  - Strategic vs tactical
- System resilience is critical
  - TBO system must be able to gracefully degrade to maintain safe operations
- Operationally-valid knowledge of the causes and mitigations of degradation must be specified for design of gracefully degrading systems

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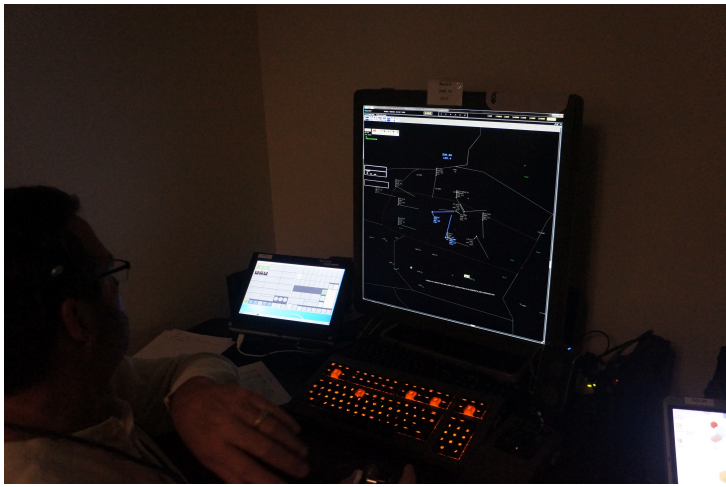
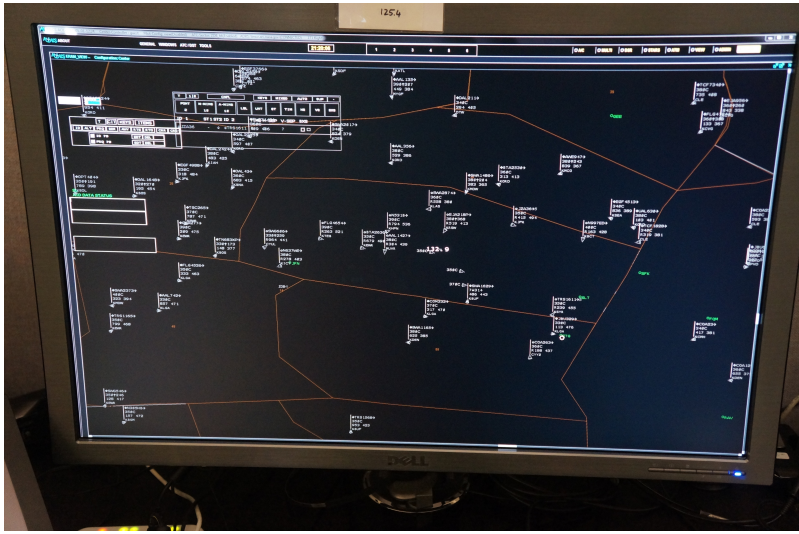
# Aims

- Identify causes of degradation in ATC
- Investigate relationships between degradation causes
- Identify prevention and mitigation mechanisms
- Understand the role of the controller in graceful degradation
- Inform understanding of the role of mental workload in graceful degradation of complex systems



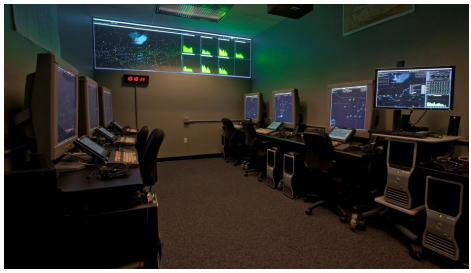


# Method

- One semi-structured interview (1 hour), one knowledge elicitation interview using scenarios (1 hour)
- Participants: 12 Retired controllers
  - TRACON and En-route experience, based in California
  - Age ranged 51 - 72 years, years of experience ranged 20-35 years
- Example questions:
  - “What has caused a ‘bad day’ in operations?”
  - “What are your control strategies for off-nominal situations?”
- Interviews transcribed orthographically and thematic analysis was used



# Result 1: Causes of degradation and the relationship with workload



- Technology
  - Failure – Radar, Communications
  - Unreliability: *"If it doesn't work we just say forget it. It's unreliable"*
  - Reduction of flexibility

*"Engineers designing routes will say, he's doing 160 knots and that's this many miles per minute, so he gets here then. [But] there's weather, there's emergencies, there's pilot errors*

- Environment: Weather, Aircraft emergencies, Pilot requests
- Complexity factors:
  - Sector features and location of sector

*"You've got to make your turns exactly right, your climbs, your speed, you've got to be on everything"*

  - Traffic level and complexity of traffic

- Human operator
  - Errors (usually as a result of):
  - Human-performance influencing factors, e.g. Workload, Fatigue, Stress, Situation Awareness

*"Somebody misses his turn and you are busy someplace else and meanwhile he has gone way past where he is supposed to go"*

# Result 1(b): Degradation cause and system effect

- Causes not sufficient to understand impact
- Relationship between cause and effect is often moderated
  - Expected or unexpected cause

    *"You did have a plan. Now you don't have a plan"*
  - Sudden or gradual cause

*"All of a sudden a bubble [thunderstorm] comes up. You just deal with what you have right in front of you"*

  - Duration
  - Traffic

    *"The pilot says, 'Can we deviate to the right around it?' I don't have any traffic out there, that's an easy thunderstorm"*

# Result 2: Relationships between causes of degradation

- Co-occurrence or association
- Between or within degradation categories

*"We had about 17 or 18 operations. It was IFR weather. Maintenance took the radar. I just barely had the picture - If I had looked away I would have lost that"*

- Interactions can result in a compound impact

*"We're very good jugglers. Something goes wrong, you can handle it. Then something else happened. Here comes another ball. Pretty soon, you're going to drop a ball"*

*"It starts to be exponential as things happen, it never seems to be linear, it just goes a lot faster"*

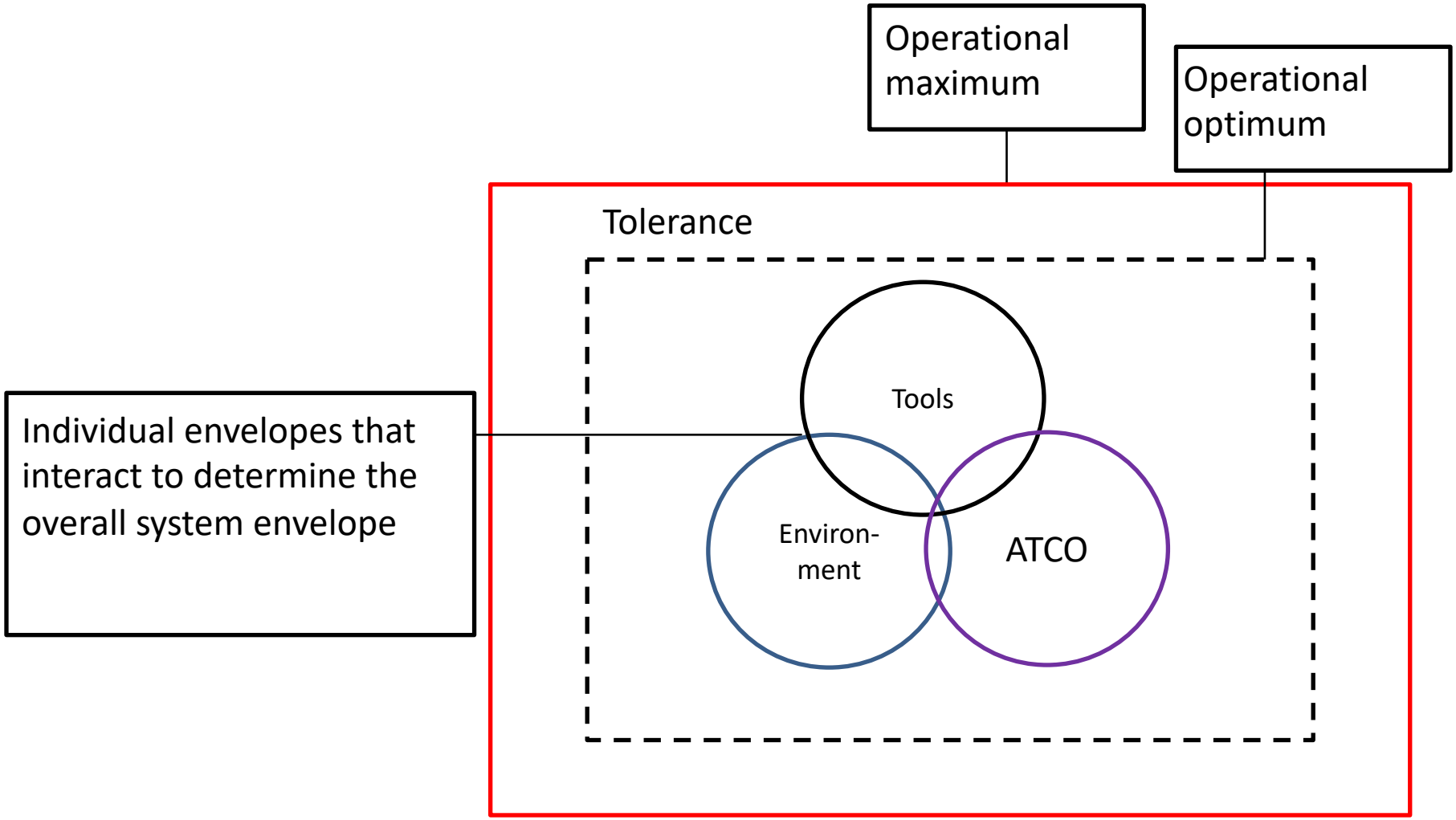
- Understanding interactions is critical:
  - Design of systems capable of graceful degradation design
  - Predicting, preventing and mitigating degradation

# Result 3: Prevention and mitigation of system degradation

- Pre-degradation strategies
- In-time prevention and mitigation strategies
  - ATCOs change control strategies to make the system work
  - Strategies have common goals of achieving more time and/or space
  - Strategies are dependent on awareness – influenced by workload
  - Strategies create workload – generating strategies as well as the striates themselves
  - Ability to generate strategies dependent on taskload and workload



# Result 4: The system performance envelope



# Conclusions & Implications

- Causes of degradation can be grouped into three broad categories
- The relationship between degradation cause and system effect is often moderated
- Identification of the interactions between causes of degradation is essential to future system design and risk assessment
- Perceived workload has a critical role in system degradation
- The concept of a system envelope can be used by designers to ensure the system stays within tolerance
- Future system design needs to be flexible for ATCOs to use mitigative strategies
- Potential interactions should be identified and designed out or mitigated

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# Thank you!

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