Cognitive Workload Assessment of ATC Units:

A case study in Mumbai Enroute airspace

Rajkumar S. Pant
Aerospace Engineering Department
IIT Bombay
rkpant@aero.iitb.ac.in

Presentation Outline

- What is Cognitive workload ?
  - Factors affecting Cognitive workload
- Approaches to assessing workload levels
  - Workload assessment in ATC units
- Details of present study
- Future Plans

Cognitive Workload

- Definition
  - Amount of mental resource required to perform a particular task, or a range of tasks, in a given operating environment
- Importance
  - Key factor in Human-Machine System
- Features
  - No direct means of measure
    - inferred from what can be seen or measured
  - Function of individual's personality
    - strongly affected by operating environment

Approaches for Workload Assessment

- Subjective Approach
  - Use of self-reporting scales through Questionnaires
- Behavioral perspective
  - Manifestation in task performance measures
- Physiological approach
  - Monitoring a range of psycho-physiological sensors
- Engineering perspective
  - Task demands + assessment of influencing factors

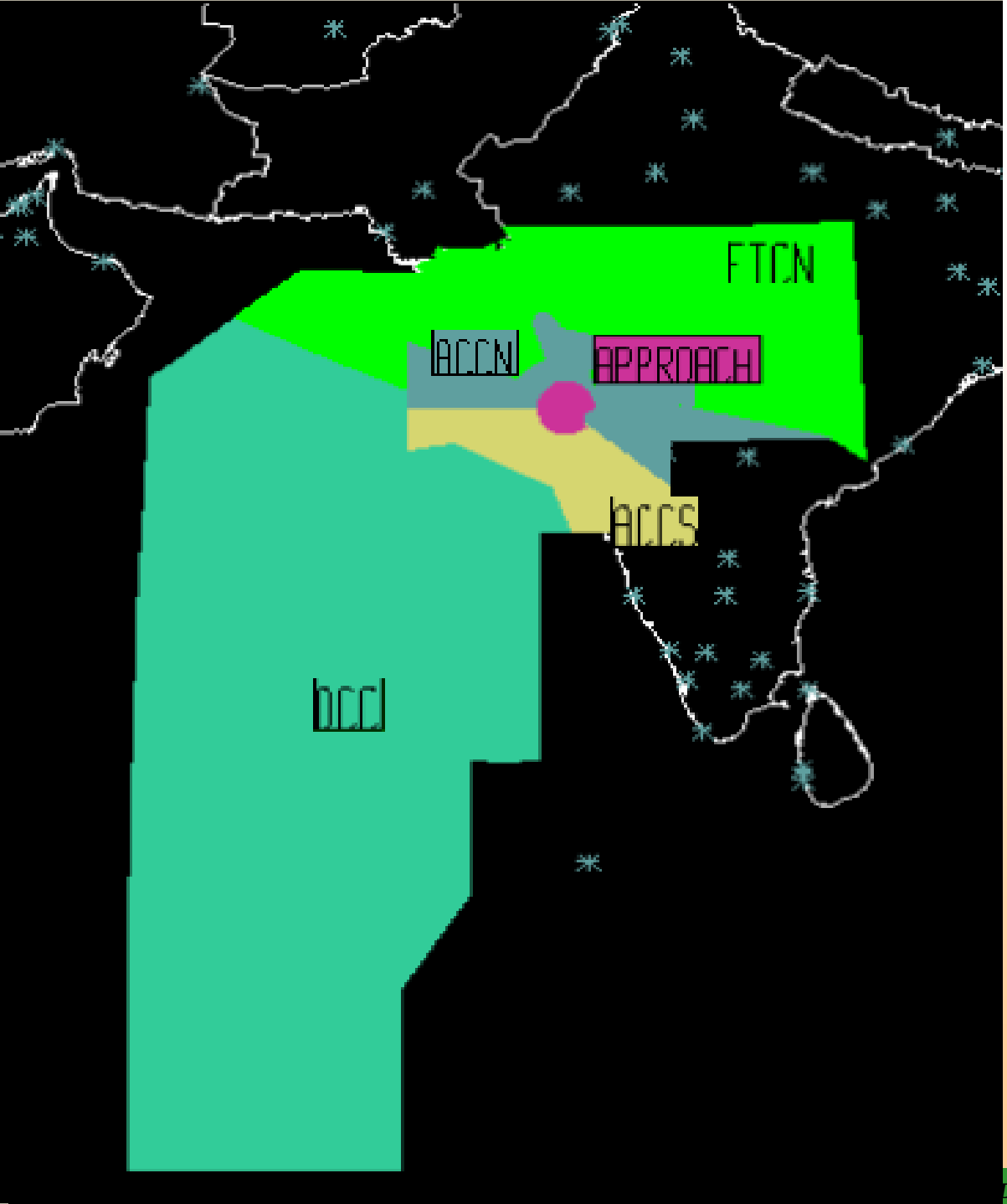
Workload Assessment of ATC units

- Dynamically changing environment
  - Rapidly changing workload levels
- Factors affecting workload
  - Task Load
  - Sector Complexity
  - Controller Performance
- Three main issues
  - Time-based factor
  - Task intensity-based factor
    - Difficulty/complexity making demands upon attention resources
  - Psycho-physiological functional state factor

Cognitive Workload Assessment in Mumbai enroute airspace

Aims of the study

- Estimate level of cognitive workload of ATCOs
- Two stations in Mumbai enroute airspace
  - ACC and OCC
- Time estimation of cognitive tasks based on
  - influential models
- Standard and specially developed rating scales
  - based on data base of activities and tasks used in literature



ATC Sectors of Mumbai FIR

The four tools

- NASA-TLX index
  - measures workload along the six dimensions
- Questionnaire: *Contributors to Workload*
  - 28 contributors identified, based on literature
  - 5 point rating scale
- Cogload: Self-rating form
  - Seven dimensions based on ATCo tasks
- RAMS CogLoad Questionnaire
  - Coupled with Blom's Human Cognition Model

Profile of ATCO volunteers

Station	ACC	OCC
No. of Volunteers	38	30
Experience (Mean) years	14.29	9.78
Age (Mean) years	40.48	36.72
Age (SD) years	5.81	6.94

NASA-Task Load Index

- Six Main scales

1. Mental demand
2. Physical demand
3. Temporal demand
4. Performance
5. Effort
6. Frustration level

- 15 subscales which are combinations of above
- 20-point bi-polar rating scale
  - Identify top two factors that affect workload

Contributors to Workload

1	2	3	4	x
Greatly	Somewhat	Minimally	Not at all*	Didn't experience**

No.	Description
1.	Traffic load (no. of aircrafts)
2.	Pilot responses-errors & delays
3.	Aircraft/pilot procedural violations
4.	Giving handoffs
5.	Planning or following the sequence
6.	Overshoots
7.	Number of altitude changes issued
8.	Pilot routing errors
9.	Pilot altitude errors
10.	Number of vectors/ routing changes issued
11.	Using the mouse / tracker ball
12.	Planning or following the runway assignment
13.	Coordinating for delayed approaches
14.	Aircraft flight characteristics
15.	Lack of a feeder controller
16.	Making runway assignment changes
17.	Using the ARTS keyboard
18.	Equipment problems/failures
19.	Accepting handoffs
20.	Pointing out aircraft
21.	Dealing with go-arounds or missed approaches
22.	Sending aircraft over the top
23.	Receiving aircraft over the top
24.	Waiting for the sequence to update
25.	RVSM/ CVSM
26.	Co-ordination with other units
27.	Non-integrated communication
28.	Number of conflict points
29.	Any other: Specify: _____

COGLOAD: Self Rating Form

Tasks	Remarks
Planning Entry	Controller is aware of an aircraft which is about to enter and start planning for its entry
Planning conflict search	The controller is engaged in establishing a blue print of how to look for conflicts.
Conflict identified	This involves identification of conflicts
Conflict resolution	Task to perform the resolution of the identified conflicts.
Sector pierce	This part of his job is performed when the aircraft has just pierced his sector.
Planning exit	Aircraft reaches a point where controller engages himself in its exit planning.
Sector exit	Demands controller to perform this task when controller is actually about to exit his sector

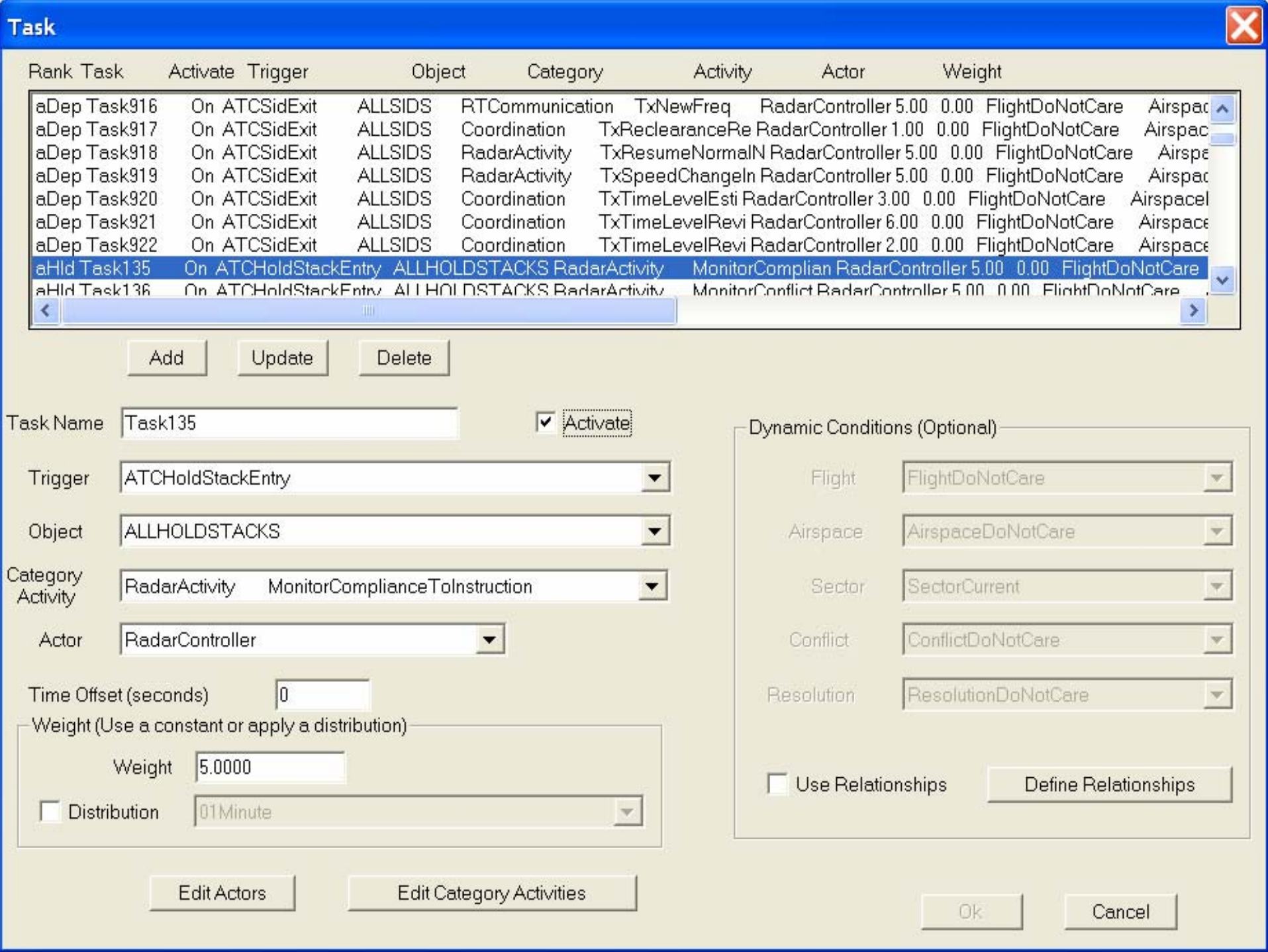
Workload Rating

- Severe:
  - Cogload in busy hour > 70 %
- Heavy
  - Cogload in busy hour ≥ 55 % but < 70%
- Moderate
  - Cogload in busy hour < 55 %

$$\text{Cogload level (ACC)} = \frac{\text{No. of aircraft managed x Cognitive time per aircraft}}{\text{Total time on Channel by all controllers}}$$

RAMS Cogload Questionnaire

- Five actors
  - Planning & Radar controller
  - Tower
  - SMC
  - Assistant 1
  - Assistant 2
- 1137 tasks defined from scratch
- Weightage to each task (time taken)
- Triggers that initiate the task
- Time offset (time diff. between two tasks)
- Resolution set of rules already defined


Task
Rank Task Activate Trigger Object Category Activity Actor Weight
aDep Task916 On ATCSidExit ALLSIDS RTCommunication TxNewFreq RadarController 5.00 0.00 FlightDoNotCare Airspac
aDep Task917 On ATCSidExit ALLSIDS Coordination TxReclearanceRe RadarController 1.00 0.00 FlightDoNotCare Airspac
aDep Task918 On ATCSidExit ALLSIDS RadarActivity TxResumeNormalN RadarController 5.00 0.00 FlightDoNotCare Airspe
aDep Task919 On ATCSidExit ALLSIDS RadarActivity TxSpeedChangeIn RadarController 5.00 0.00 FlightDoNotCare Airspac
aDep Task920 On ATCSidExit ALLSIDS Coordination TxTimeLevelEsti RadarController 3.00 0.00 FlightDoNotCare Airspacel
aDep Task921 On ATCSidExit ALLSIDS Coordination TxTimeLevelRevi RadarController 6.00 0.00 FlightDoNotCare Airspace
aDep Task922 On ATCSidExit ALLSIDS Coordination TxTimeLevelRevi RadarController 2.00 0.00 FlightDoNotCare Airspace
aHld Task135 On ATCHoldStackEntry ALLHOLDSTACKS RadarActivity MonitorComplian RadarController 5.00 0.00 FlightDoNotCare
Add
Update
Delete
Task Name
Task135
Activate
Trigger
ATCHoldStackEntry
Object
ALLHOLDSTACKS
Category Activity
RadarActivity
MonitorComplianceToInstruction
Actor
RadarController
Time Offset (seconds)
0
Weight (Use a constant or apply a distribution)
Weight
5.0000
Distribution
01Minute
Dynamic Conditions (Optional)
Flight
FlightDoNotCare
Airspace
AirspaceDoNotCare
Sector
SectorCurrent
Conflict
ConflictDoNotCare
Resolution
ResolutionDoNotCare
Use Relationships
Define Relationships
Edit Actors
Edit Category Activities
Ok
Cancel

Results at a Glance

Table 5.1 Summary of responses from 38 controllers in ACC

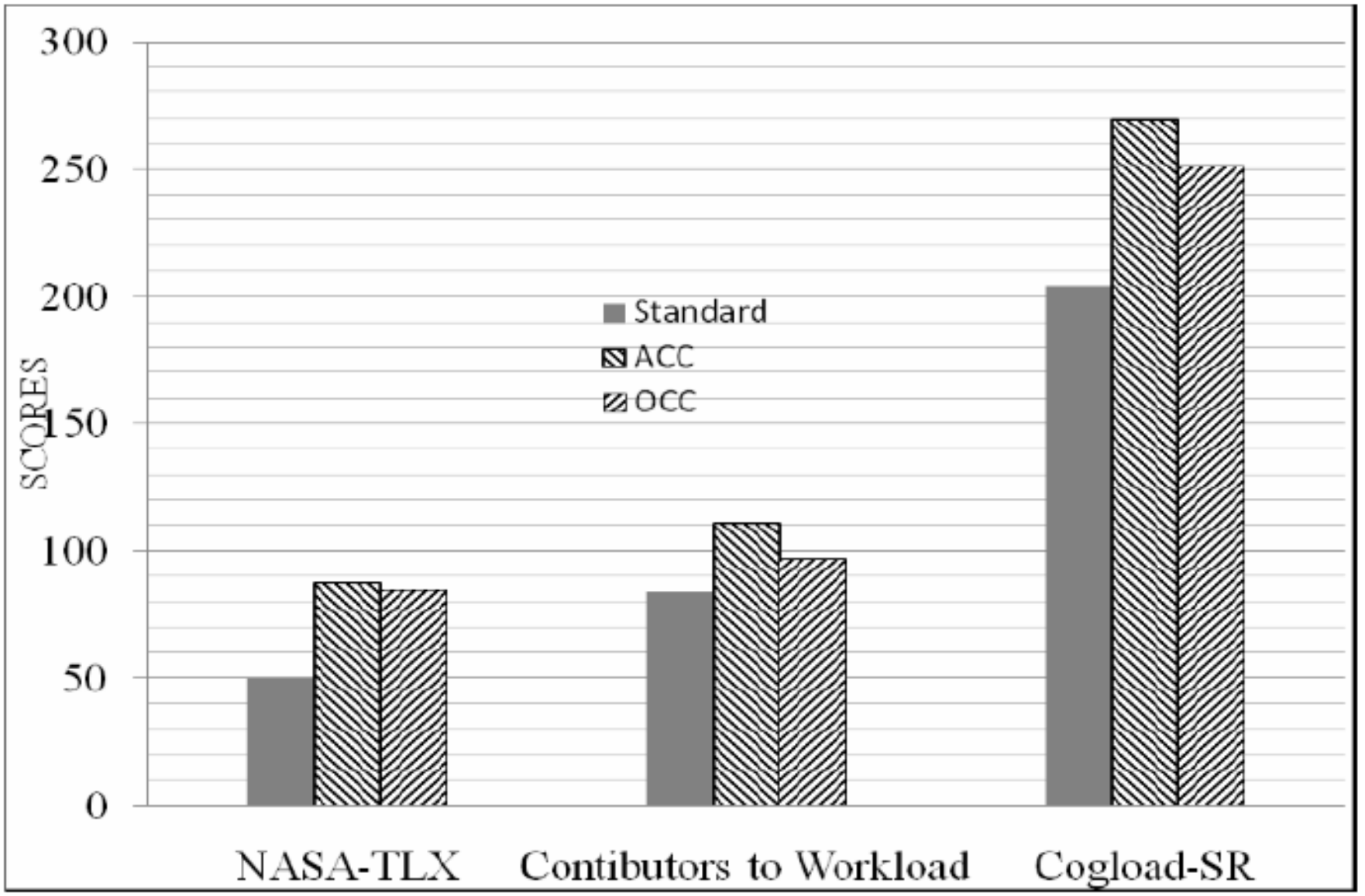
Scale	Complete Responses	Score	Standard Deviation
NASA-TLX	32	87.06 %	8.02 %
Contributors to Workload	38	110.73	15.06
Cogload: Self Rating Form	38	268.78	31.85
RAMS Cogload Questionnaire	29	6.25 min	4.82 min

Table 5.2 Summary of responses from 30 controllers in OCC

Scale	Complete Responses	Score	Standard Deviation
NASA-TLX	27	85.65 %	11.11 %
Contributors to Workload	27	96.81	17.97
Cogload: Self Rating Form	26	250.54	46.54
RAMS Cogload Questionnaire	21	19.86 min	12.34 min

- Key Observations
  - Both positions show overload on tools of assessment used in the study
  - Higher (severe) overload in OCC compared to ACC on RAMS-Cogload
    - Primarily due to communication load and absence of radar coverage

Comparison of scores



Observations & Conclusions

- High to very-high workload observed
  - Self-report questionnaire + time estimates
    - Subjective measures report Higher workload in ACC
    - However, time required to do activities is larger !
      - ACC controllers more experienced
- Limitations
  - Biased outcomes possible due to self-reporting
    - Will ATCOs appear to be "inefficient" ?
  - OCC and ACC population not homogenous
  - Small population size
    - Over 120 ATCOs approached, only 68 volunteered !

Future Work

- Extending scope of the study
  - Other FIRs
- Use of direct physiological methods
  - Eyeball tracking
  - non-intrusive biological measurements
    - Skin conductivity
    - Cardiovascular activity
    - Respiration
    - Brain's electric activity
    - Body temperature

Open for Discussion

Thanks to ATC Guild (India) for giving us an opportunity to share this work !