STPA for Airports

safety hazard analysis for aircraft operations in hub airports

Idoaldo J Lima Claudio J P Alves Carlos H N Lahoz
Aeronautics Institute of Technology - ITA (Brazil)

2018 MIT STAMP/STPA Workshop - March 29

Disclaimer

The views, opinions and assumptions expressed in this presentation are those of the authors and do not necessarily reflect the official policy or position of the Brazilian Government or any of its organisations, including the Aeronautic Technology Institute (ITA), or of the Massachusetts Institute of Technology (MIT). Examples of analysis performed within this presentation are part of an ongoing work yet to be finished and made available. They should not be applied in real-world analytic products as they are based in dated public source information.

Agenda

1. context & prior work
    a. on going
    b. main idea
2. what & how
    a. process overview
    b. airport groups
    c. accidents of interest
    d. case study
3. applying STPA
    a. foundations
    b. unsafe controls
    c. scenarios
4. contributions

1. CONTEXT & PRIOR WORK
2. WHAT & HOW
3. APPLYING STPA
4. CONTRIBUTIONS

on going work

Master's in Air Transportation and Airports
Aviation Infrastructure Engineering Graduate Program
Aeronautics Institute of Technology - ITA

STAMP Approach Applied to Safety Hazard Analysis in Brazilian Airport Infrastructure

supervisor: Prof. Claudio J P Alves
co-supervisor: Prof. Carlos H N Lahoz

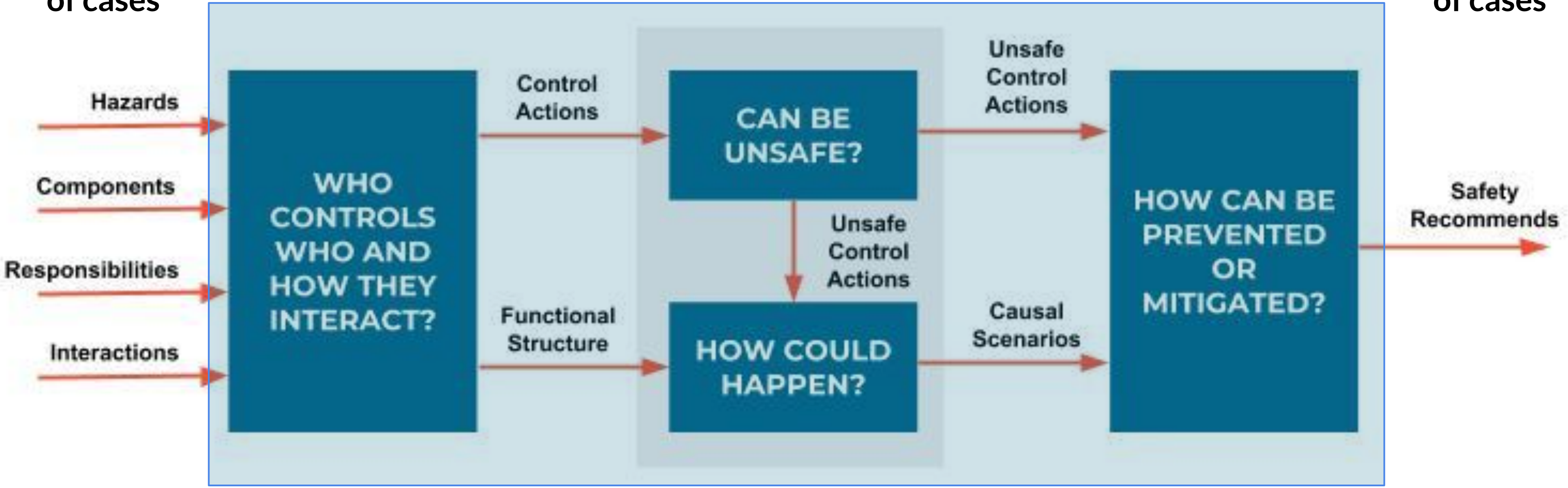
objective: **" to analyse safety hazards in aircraft operations for Brazilian airports using STPA and propose recommendations "**

main idea on how

common INPUTS from group of cases

“ THE STPA PROCESS “

common OUTPUTS for group of cases



extendable results, less time and effort for analyses

1. CONTEXT & PRIOR WORK
2. **WHAT & HOW**
3. APPLYING STPA
4. CONTRIBUTIONS

process overview

AIRPORTS & ACCIDENTS GROUPING	STPA ANALYSIS	RECOMMENDATIONS GENERATION
use safety context attributes to group airports and accidents	apply STPA analysis within airports groups and accident types	produce recommendations for airports within groups
Airport Characterization Through System Safety Contexts	***STPA for Airports safety hazard analysis for aircraft operations in hub airports***	***Master's dissertation and paper***
at SITRAER 2017	**at 2018 MIT STAMP Workshop**	**at ITA Infra July 2018**

airport groups

"Airport Characterization Through System Safety Contexts"
at SITRAER 2017

method: Two-Step Cluster Analysis
attributes:

APPROACH
level of precision available
PA1/2/3A, NPA, NINST

MOVEMENT
annual aircraft movs
last 10 years average

SECURITY
protection levels
AP-3/2/1/0 or AD

OPERATION
maintenance & emergency standards
Class I, II, III or IV

FEEING
category
1st, 2nd, 3rd, 4th Class or Concession

airport clusters

CLUSTER 1	CLUSTER 2	CLUSTER 3	CLUSTER 4	CLUSTER 5
AP-1 100%	AP-0 100%	AP-2 100%	AD 58,54% AP-1 41,46%	AP-3 100,00%
Class I 66,67% Class II 33,33%	Class I 96,67% Class II 3,33%	Class II 20,83% Class III 79,17%	Class I 100%	Classe IV 100%
57 airports	**30 airports**	**24 airports**	**41 airports**	**12 airports**
1ª 1,75% 2ª 50,88% 3ª 45,61%	2ª 10,00% 3ª 26,67% 4ª 63,33%	1ª 29,17% 2ª 66,67% 1ª (*) 4,17%	4ª 19,51% - 80,49%	1ª (*) 41,67% 1ª 58,33%
REGIONAL Airports	**LOCAL Airports**	**DOMESTIC Airports**	**LOCAL Airports**	**INT. HUB Airports**
NINST 22,81% NPA 66,67% PA1 10,53%	NINST 56,67% NPA 40,00% PA1 3,33%	NPA 66,67% PA1 33,33%	NINST 75,61% NPA 24,39%	PA1 58,33% PA2 25,00% PA3-A 8,33%
2335 mov/y	635 mov/y	14725 mov/y	461 mov/y	92552 mov/y

case study

MAJOR HUB AIRPORTS (cluster 5)

BSB	Brasília
CNF	Confins
CWB	Curitiba
FOR	Fortaleza
GIG	Galeão
GRU	Guarulhos
VCP	Campinas
POA	Porto Alegre
REC	Recife
SDU	Rio de Janeiro
CGH	São Paulo
SSA	Salvador

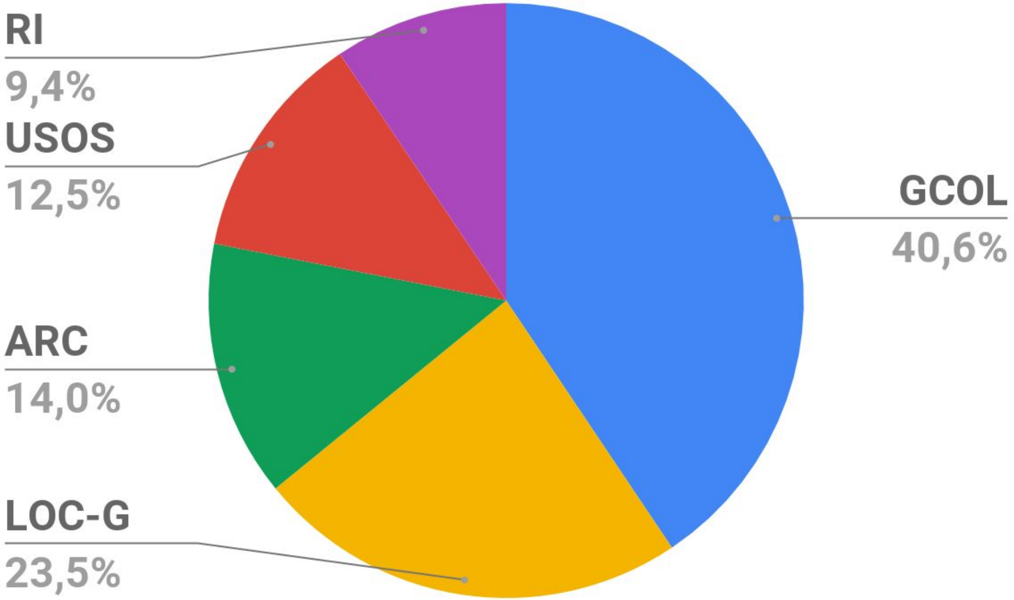
AIRPORTS & ACCIDENTS GROUPING ▶ STPA ANALYSIS ▶ RECOMMENDATIONS GENERATION

accidents of interest

ARC	abnormal runway contact
GCOL	**ground collision**
LOC-G	loss of control on ground
RE	runway excursion
RI	runway incursion
USOS	undershoot/overshoot

TOF	takeoff
APR	approach
LDG	landing
TXI	**taxi**
STD	**standing**

CLUSTER 5 - MAJOR HUB AIRPORTS in Brazil



AIRPORTS & ACCIDENTS GROUPING ▶ STPA ANALYSIS ▶ RECOMMENDATIONS GENERATION

case study

"STPA for aircraft operations in major hub airports"
at MIT STAMP 2018

" GROUND COLLISION occurrences during TAXI and STANDING phases for the Brazilian MAJOR HUB AIRPORTS (cluster 5) "

21 reports

from CENIPA

(Brazilian equivalent to NTSB for aviation)

www2.fab.mil.br/cenipa

AIRPORTS & ACCIDENTS GROUPING ▶ **STPA ANALYSIS** ▶ RECOMMENDATIONS GENERATION

GCOL during TXI or STD

WHERE DID IT HAPPEN?

BSB	**Brasília**	**5**
CNF	Confins	0
CWB	**Curitiba**	**1**
FOR	Fortaleza	0
GIG	**Galeão**	**4**
GRU	**Guarulhos**	**5**
VCP	Campinas	0
POA	**Porto Alegre**	**1**
REC	Recife	0
SDU	**Rio de Janeiro**	**1**
CGH	**São Paulo**	**2**
SSA	**Salvador**	**2**

case study

“ GROUND COLLISION occurrences during TAXI and STANDING phases for the Brazilian MAJOR HUB AIRPORTS (cluster 5) ”

GROUND COLLISION
aircraft impact against AIRCRAFT, OBSTACLE or VEHICLE

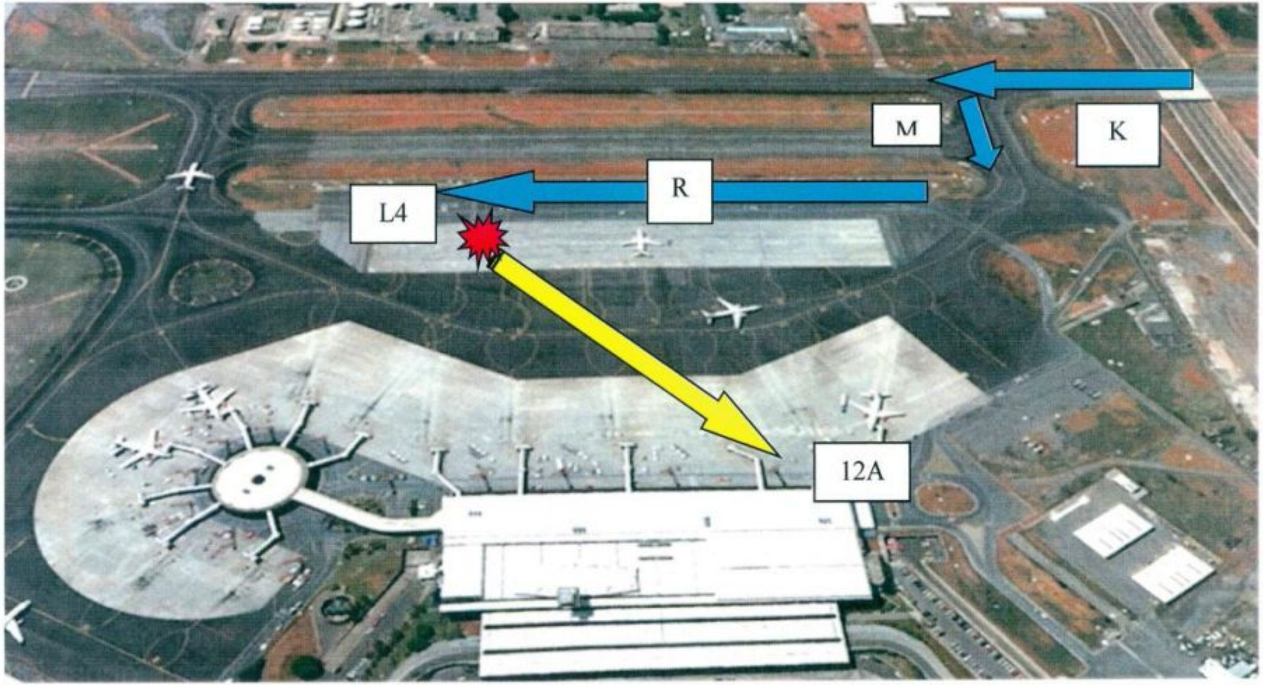
TAXI & STANDING
aircraft in movement or not, on the surface of aerodrome excluded TOF and LDG

MAJOR HUB AIRPORTS (cluster 5)
BSB CNF CWB FOR GIG GRU
VCP POA REC SDU CGH SSA

case study

GROUND COLLISION
during
TAXI & STANDING

A330 against floodlight tower at BSB in 2013



http://www.potter.net.br/show_fnco/201304131652552

case study

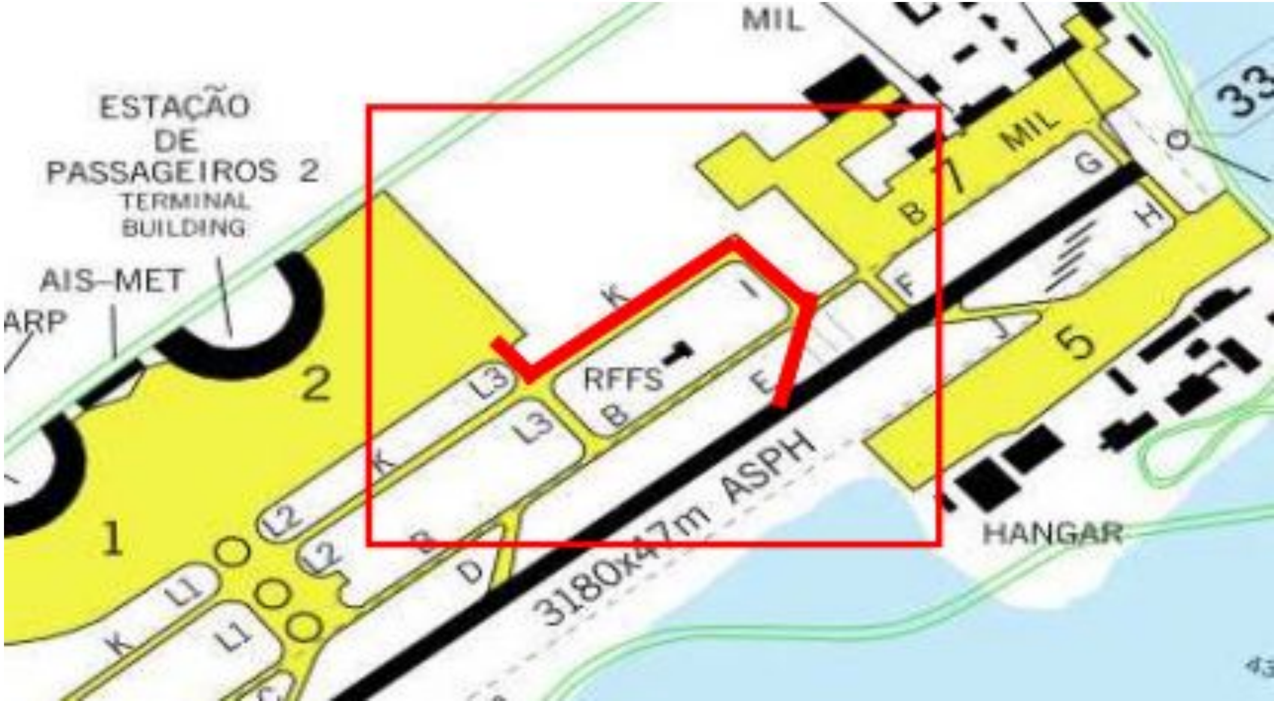
GROUND COLLISION
during
TAXI & STANDING

A330 against floodlight tower at BSB in 2013

case study

GROUND COLLISION
during
TAXI & STANDING

B777 against B737 at GIG in 2013



http://www.potter.net.br/show_fnco/201309047438886

case study

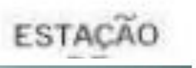
GROUND COLLISION
during
TAXI & STANDING

B777 against B737 at GIG in 2013

case study

GROUND COLLISION
during
TAXI & STANDING

B777 against B737 at GIG in 2013



1. CONTEXT & PRIOR WORK
2. WHAT & HOW
3. **APPLYING STPA**
4. CONTRIBUTIONS

losses

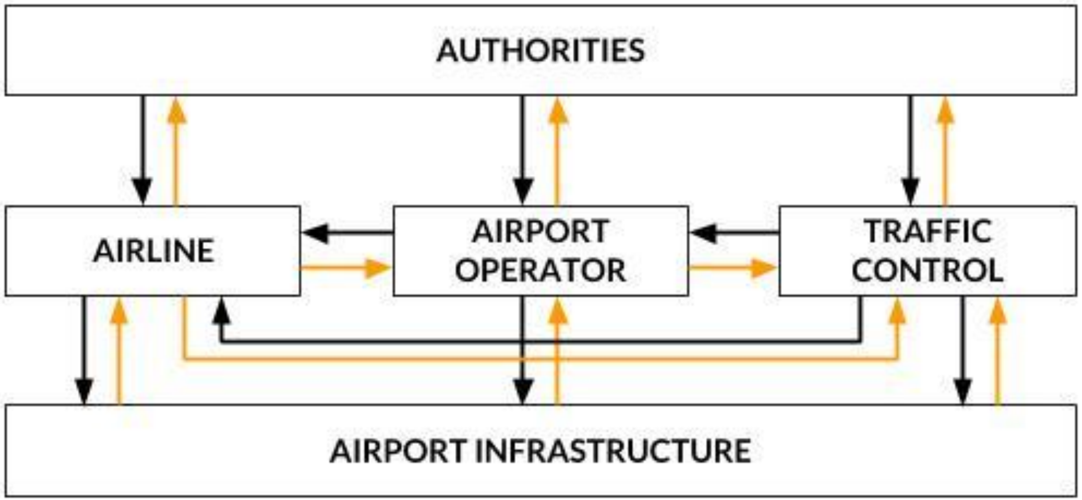
Case
Ground collision occurrence during aircraft operations on the ground in major hub airports.

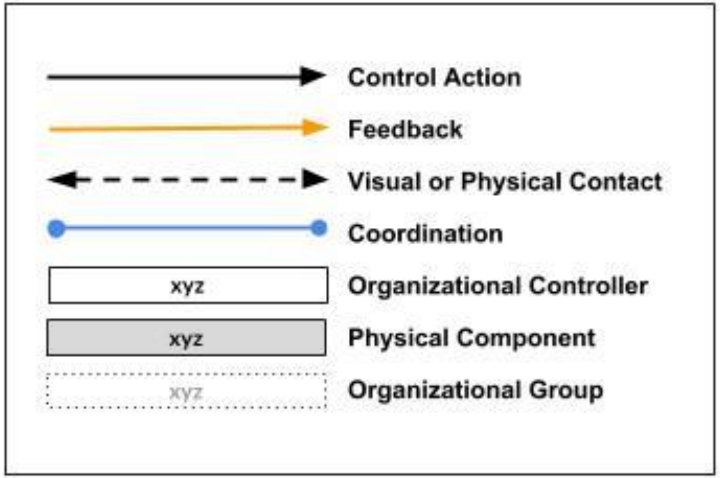
L-1	Loss of life or injury to people	(0 occurrences)
L-2	Loss of or damage to aircraft	(21 occurrences)
L-3	Loss of or damage to service vehicle/equipment	(11 occurrences)
L-4	Loss of or damage to infrastructure components	(8 occurrences)
L-5	Loss of transportation	(18 occurrences)

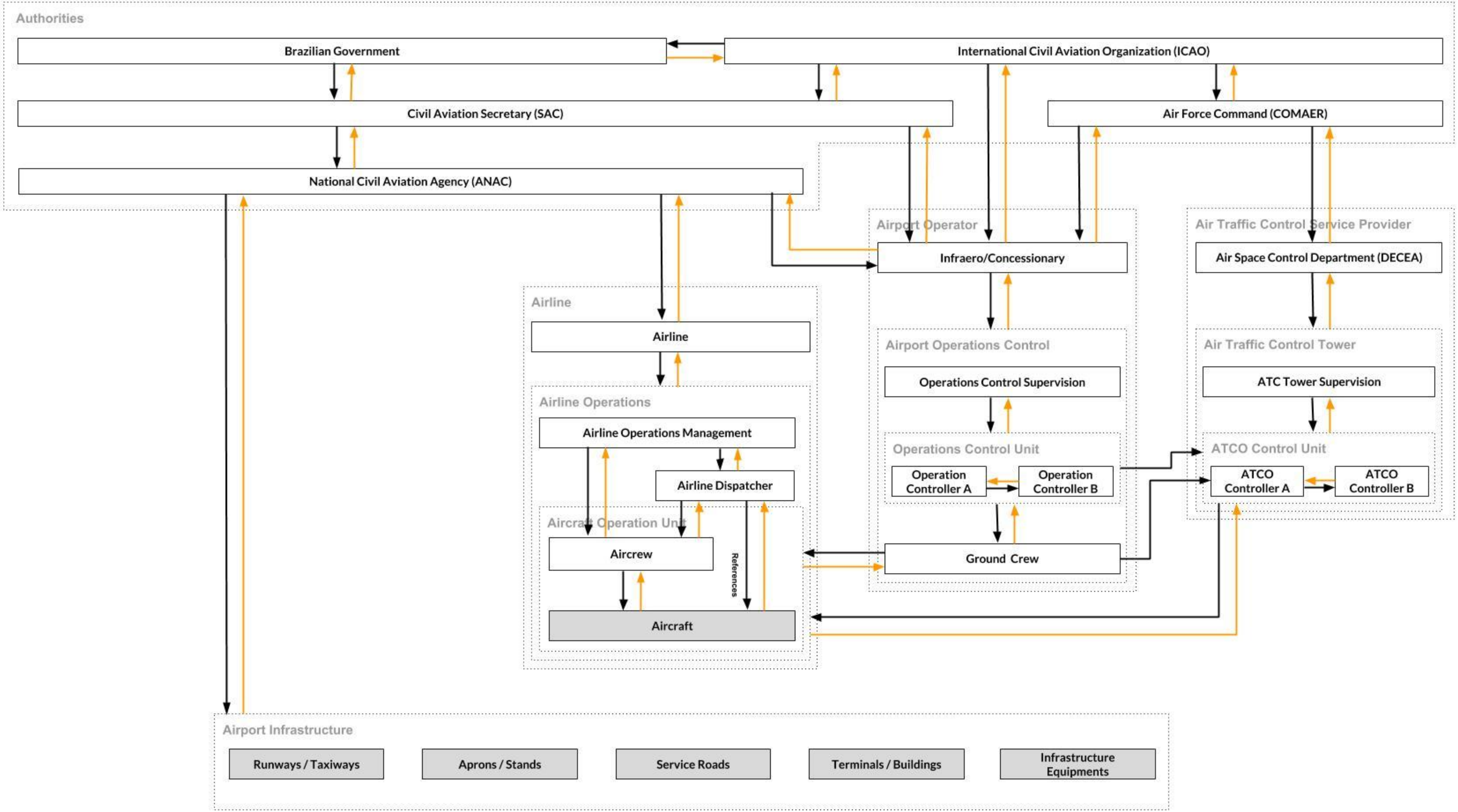
hazards

H-1 Aircraft violates the minimum separation from other aircrafts during operations on the ground [L-1, L-2, L-5]
H-2 Aircraft violates the minimum separation from service vehicles during operations on the ground [L-1, L-2, L-3, L-5]
H-3 Aircraft comes too close to service equipment components during operations on the ground [L-1, L-2, L-3, L-5]
H-4 Aircraft comes too close to airport infrastructure components during operations on the ground [L-1, L-2, L-4, L-5]
H-5 Airframe integrity is lost during operations on the ground [L-1, L-2, L-5]
H-6 Service vehicle/equipment frame integrity is lost during operations on the ground [L-1, L-3, L-4]
H-7 Airport infrastructure component integrity is lost during operations [L-1, L-2, L-3, L-4, L-5]
H-8 Human physical integrity is lost during operations [L-1, L-5]

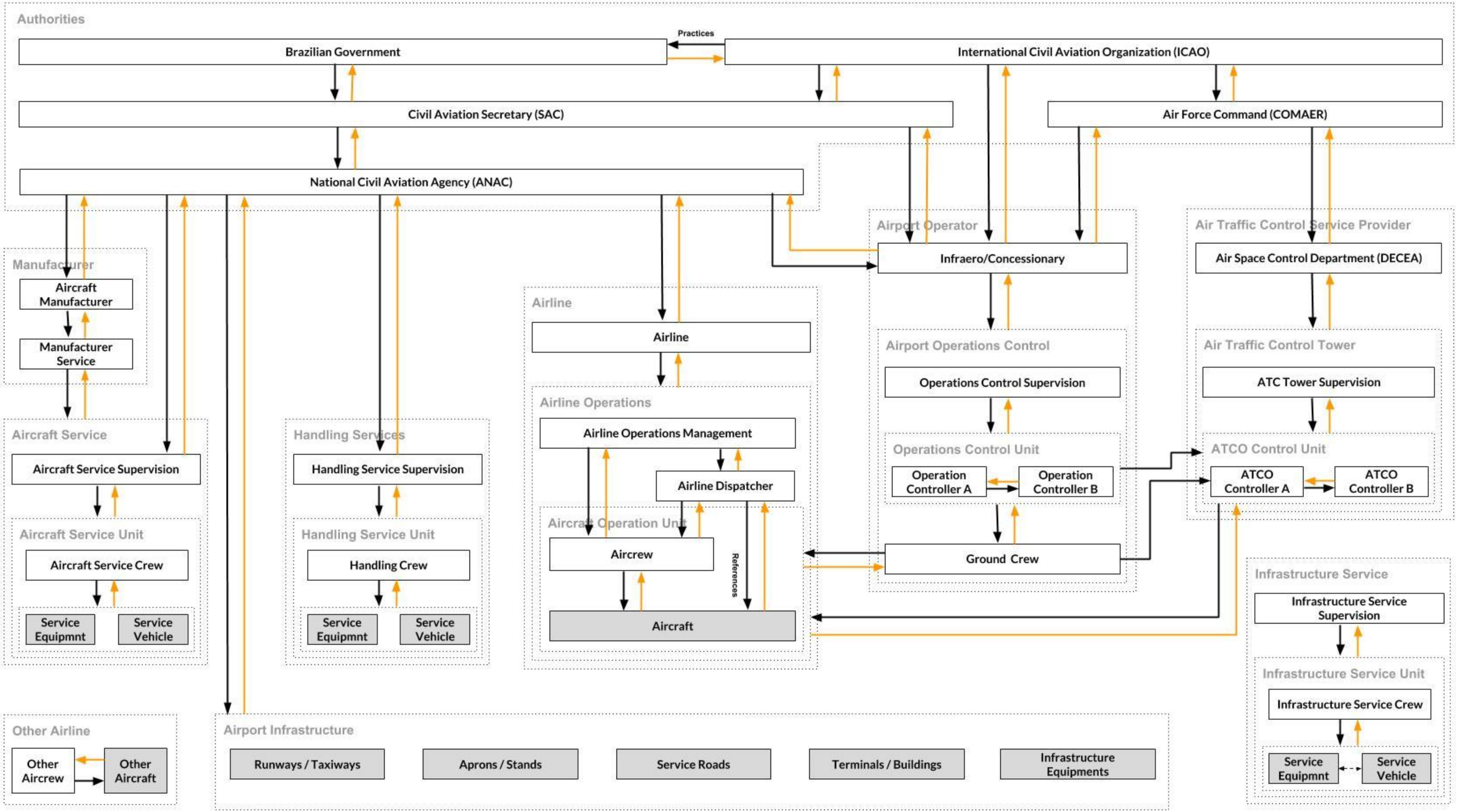
functional control structure



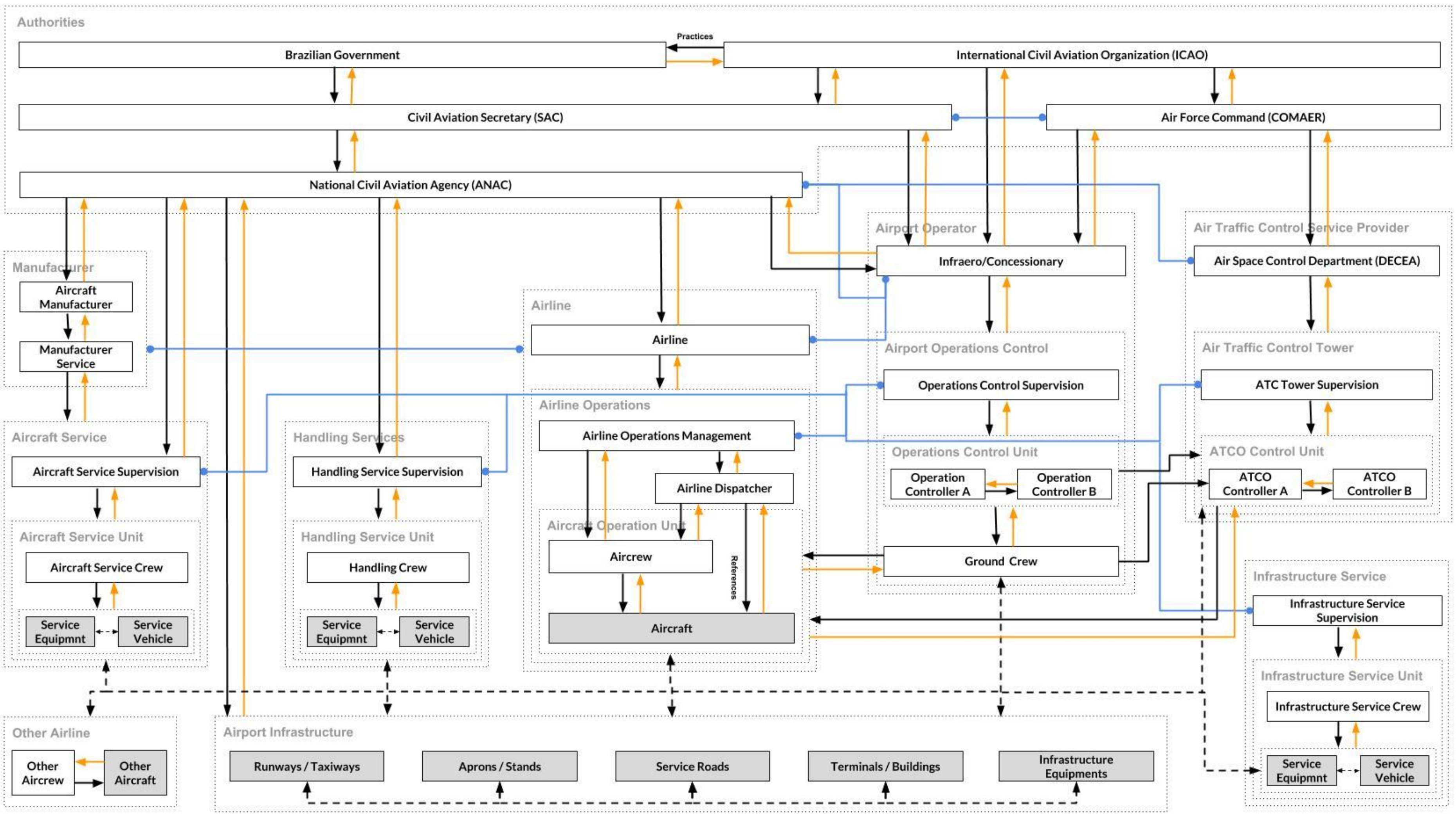




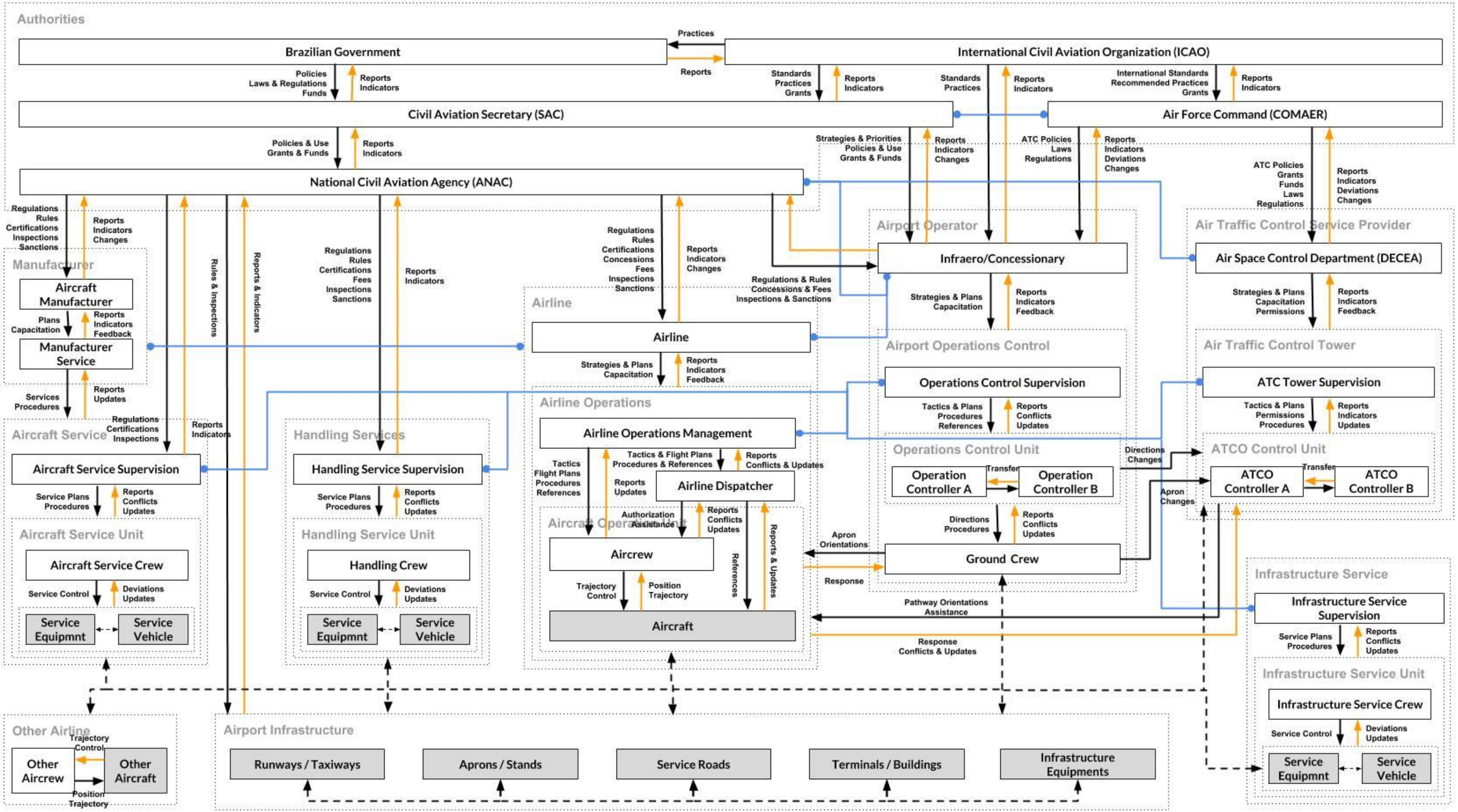
Authorities
Brazilian Government
International Civil Aviation Organization (ICAO)
Civil Aviation Secretary (SAC)
Air Force Command (COMAER)
National Civil Aviation Agency (ANAC)
Airport Operator
Infraero/Concessionary
Air Traffic Control Service Provider
Air Space Control Department (DECEA)
Airline
Airline
Airline Operations
Airline Operations Management
Airline Dispatcher
Aircraft Operation Unit
Aircrew
References
Aircraft
Airport Operations Control
Operations Control Supervision
Operations Control Unit
Operation Controller A
Operation Controller B
Ground Crew
Air Traffic Control Tower
ATC Tower Supervision
ATCO Control Unit
ATCO Controller A
ATCO Controller B
Airport Infrastructure
Runways / Taxiways
Aprons / Stands
Service Roads
Terminals / Buildings
Infrastructure Equipments



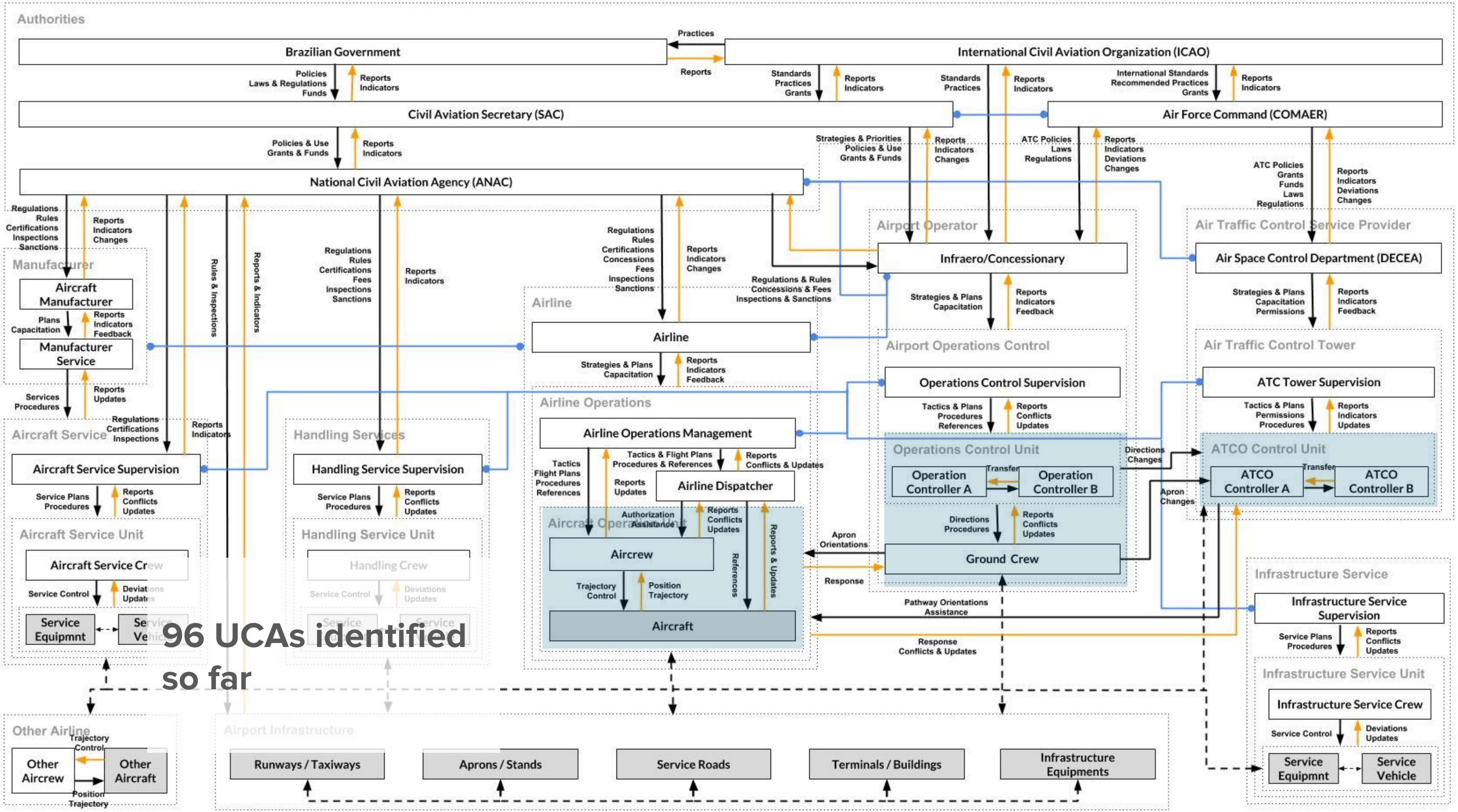
Authorities
Practices
Brazilian Government
International Civil Aviation Organization (ICAO)
Civil Aviation Secretary (SAC)
Air Force Command (COMAER)
National Civil Aviation Agency (ANAC)
Manufacturer
Aircraft Manufacturer
Manufacturer Service
Airport Operator
Infraero/Concessionary
Air Traffic Control Service Provider
Air Space Control Department (DECEA)
Airline
Airline
Airport Operations Control
Operations Control Supervision
Air Traffic Control Tower
ATC Tower Supervision
Airline Operations
Airline Operations Management
Aircraft Service
Aircraft Service Supervision
Handling Services
Handling Service Supervision
Airline Dispatcher
Operations Control Unit
Operation Controller A
Operation Controller B
ATCO Control Unit
ATCO Controller A
ATCO Controller B
Aircraft Service Unit
Aircraft Service Crew
Handling Service Unit
Handling Crew
Aircraft Operation Unit
Aircrew
References
Ground Crew
Service Equipmnt
Service Vehicle
Service Equipmnt
Service Vehicle
Aircraft
Infrastructure Service
Infrastructure Service Supervision
Infrastructure Service Unit
Infrastructure Service Crew
Service Equipmnt
Service Vehicle
Other Airline
Other Aircrew
Other Aircraft
Airport Infrastructure
Runways / Taxiways
Aprons / Stands
Service Roads
Terminals / Buildings
Infrastructure Equipments



Authorities
Practices
Brazilian Government
International Civil Aviation Organization (ICAO)
Civil Aviation Secretary (SAC)
Air Force Command (COMAER)
National Civil Aviation Agency (ANAC)
Airport Operator
Infraero/Concessionary
Air Traffic Control Service Provider
Air Space Control Department (DECEA)
Manufacturer
Aircraft Manufacturer
Manufacturer Service
Airline
Airline
Airport Operations Control
Operations Control Supervision
Air Traffic Control Tower
ATC Tower Supervision
Airline Operations
Airline Operations Management
Aircraft Service
Aircraft Service Supervision
Handling Services
Handling Service Supervision
Operations Control Unit
Operation Controller A
Operation Controller B
ATCO Control Unit
ATCO Controller A
ATCO Controller B
Airline Dispatcher
Aircraft Service Unit
Aircraft Service Crew
Handling Service Unit
Handling Crew
Aircraft Operation Unit
Aircrew
References
Ground Crew
Infrastructure Service
Infrastructure Service Supervision
Service Equipmnt
Service Vehicle
Service Equipmnt
Service Vehicle
Aircraft
Infrastructure Service Unit
Infrastructure Service Crew
Other Airline
Other Aircrew
Other Aircraft
Airport Infrastructure
Runways / Taxiways
Aprons / Stands
Service Roads
Terminals / Buildings
Infrastructure Equipments
Service Equipmnt
Service Vehicle



Authorities
Brazilian Government
International Civil Aviation Organization (ICAO)
Practices
Reports
Policies
Laws & Regulations
Funds
Reports
Indicators
Standards
Practices
Grants
Reports
Indicators
Standards
Practices
Reports
Indicators
International Standards
Recommended Practices
Grants
Reports
Indicators
Civil Aviation Secretary (SAC)
Air Force Command (COMAER)
Policies & Use
Grants & Funds
Reports
Indicators
Strategies & Priorities
Policies & Use
Grants & Funds
Reports
Indicators
Changes
ATC Policies
Laws
Regulations
Reports
Indicators
Deviations
Changes
ATC Policies
Grants
Funds
Laws
Regulations
Reports
Indicators
Deviations
Changes
National Civil Aviation Agency (ANAC)
Regulations
Rules
Certifications
Inspections
Sanctions
Reports
Indicators
Changes
Rules & Inspections
Reports & Indicators
Regulations
Rules
Certifications
Fees
Inspections
Sanctions
Reports
Indicators
Regulations
Rules
Certifications
Concessions
Fees
Inspections
Sanctions
Reports
Indicators
Changes
Regulations & Rules
Concessions & Fees
Inspections & Sanctions
Airport Operator
Infraero/Concessionary
Air Traffic Control Service Provider
Air Space Control Department (DECEA)
Manufacturer
Aircraft Manufacturer
Plans
Capacitation
Reports
Indicators
Feedback
Manufacturer Service
Services
Procedures
Reports
Updates
Airline
Airline
Strategies & Plans
Capacitation
Reports
Indicators
Feedback
Strategies & Plans
Capacitation
Reports
Indicators
Feedback
Strategies & Plans
Capacitation
Permissions
Reports
Indicators
Feedback
Airport Operations Control
Operations Control Supervision
Tactics & Plans
Procedures
References
Reports
Conflicts
Updates
Air Traffic Control Tower
ATC Tower Supervision
Tactics & Plans
Permissions
Procedures
Reports
Indicators
Updates
Airline Operations
Airline Operations Management
Regulations
Certifications
Inspections
Reports
Indicators
Aircraft Service
Aircraft Service Supervision
Service Plans
Procedures
Reports
Conflicts
Updates
Aircraft Service Unit
Aircraft Service Crew
Service Control
Deviations
Updates
Service Equipmnt
Service Vehicle
Handling Services
Handling Service Supervision
Service Plans
Procedures
Reports
Conflicts
Updates
Handling Service Unit
Handling Crew
Service Control
Deviations
Updates
Service Equipmnt
Service Vehicle
Tactics
Flight Plans
Procedures
References
Tactics & Flight Plans
Procedures & References
Reports
Conflicts & Updates
Reports
Updates
Airline Dispatcher
Aircraft Operations Unit
Authorization
Assistance
Reports
Conflicts
Updates
References
Reports & Updates
Aircrew
Trajectory
Control
Position
Trajectory
Aircraft
Operations Control Unit
Operation Controller A
Transfer
Operation Controller B
Directions
Procedures
Reports
Conflicts
Updates
Ground Crew
Apron
Orientations
Response
Directions
Changes
ATCO Control Unit
ATCO Controller A
Transfer
ATCO Controller B
Apron
Changes
Pathway Orientations
Assistance
Response
Conflicts & Updates
Infrastructure Service
Infrastructure Service Supervision
Service Plans
Procedures
Reports
Conflicts
Updates
Infrastructure Service Unit
Infrastructure Service Crew
Service Control
Deviations
Updates
Service Equipmnt
Service Vehicle
Other Airline
Trajectory
Control
Other Aircrew
Other Aircraft
Position
Trajectory
Airport Infrastructure
Runways / Taxiways
Aprons / Stands
Service Roads
Terminals / Buildings
Infrastructure Equipments


Authorities
Brazilian Government
International Civil Aviation Organization (ICAO)
Practices
Reports
Policies
Laws & Regulations
Funds
Reports
Indicators
Standards
Practices
Grants
International Standards
Recommended Practices
Grants
Civil Aviation Secretary (SAC)
Air Force Command (COMAER)
Policies & Use
Grants & Funds
Strategies & Priorities
ATC Policies
Laws
Regulations
Deviations
Changes
National Civil Aviation Agency (ANAC)
Regulations
Rules
Certifications
Inspections
Sanctions
Concessions
Fees
Rules & Inspections
Reports & Indicators
Manufacturer
Aircraft Manufacturer
Plans
Capacitation
Feedback
Manufacturer Service
Services
Procedures
Updates
Airport Operator
Infraero/Concessionary
Air Traffic Control Service Provider
Air Space Control Department (DECEA)
Regulations & Rules
Concessions & Fees
Inspections & Sanctions
Strategies & Plans
Capacitation
Permissions
Airline
Airport Operations Control
Operations Control Supervision
Air Traffic Control Tower
ATC Tower Supervision
Airline Operations
Airline Operations Management
Aircraft Service
Aircraft Service Supervision
Handling Services
Handling Service Supervision
Tactics & Plans
Procedures
References
Conflicts
Tactics
Flight Plans
Tactics & Flight Plans
Procedures & References
Conflicts & Updates
Airline Dispatcher
Operations Control Unit
Operation Controller A
Operation Controller B
Transfer
ATCO Control Unit
ATCO Controller A
ATCO Controller B
Directions
Changes
Apron Changes
Service Plans
Aircraft Service Unit
Handling Service Unit
Aircraft Operations Unit
Authorization
Assistance
Aircrew
Ground Crew
Apron Orientations
Response
Aircraft Service Crew
Handling Crew
Service Control
Deviations
Trajectory Control
Position Trajectory
Aircraft
Pathway Orientations
Assistance
Response
Conflicts & Updates
Infrastructure Service
Infrastructure Service Supervision
Infrastructure Service Unit
Infrastructure Service Crew
Service Equipmnt
Service Vehicle
Other Airline
Other Aircrew
Other Aircraft
Airport Infrastructure
Runways / Taxiways
Aprons / Stands
Service Roads
Terminals / Buildings
Infrastructure Equipments
96 UCAs identified so far

unsafe control actions

for the Control Action:

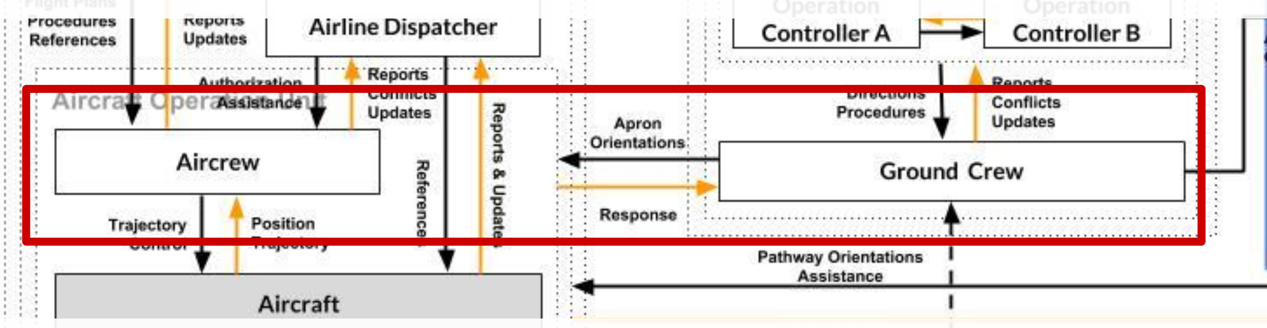
from Gnd Crew to Aircrew

GndCrew-CA-1: Apron Orientation

CA-1.1: Access Apron

CA-1.2: Transit through Apron

CA-1.3: Hold position



Control Actions from Gnd Crew to Aircrew	Not providing causes hazard	Providing causes hazard	Too early, too late, out of order	Stopping too soon, applying too long
Access Apron	**UCA-1**: when the alternative is restricted/closed and hold position is not an option	**UCA-2**: when there are latent restrictions ahead **UCA-3**: when it should be for Other Aircrew	**UCA-4**: when it is no longer possible	N/A
Transit through Apron	**UCA-5**: when the alternative is restricted/closed and hold position is not an option	**UCA-6**: when there are latent restrictions ahead **UCA-7**: when it should be for Other Aircrew	**UCA-8**: too late, when it is no longer possible **UCA-9**: in the wrong order, during normal operations	**UCA-10**: for too long, when there are latent restrictions/obstacles ahead
Hold position	**UCA-11**: when there are latent restrictions/obstacles ahead	**UCA-12**: during normal operations without any restrictions/obstacles ahead **UCA-13**: when it should be for Other Aircrew	**UCA-14**: too soon, during normal operations **UCA-15**: too late, when it is no longer possible **UCA-16**: in the wrong order, during normal operations	**UCA-17**: for too long, when there are latent restrictions/obstacles about to take place **UCA-18**: stop too soon, when there are latent restrictions/obstacles still in place

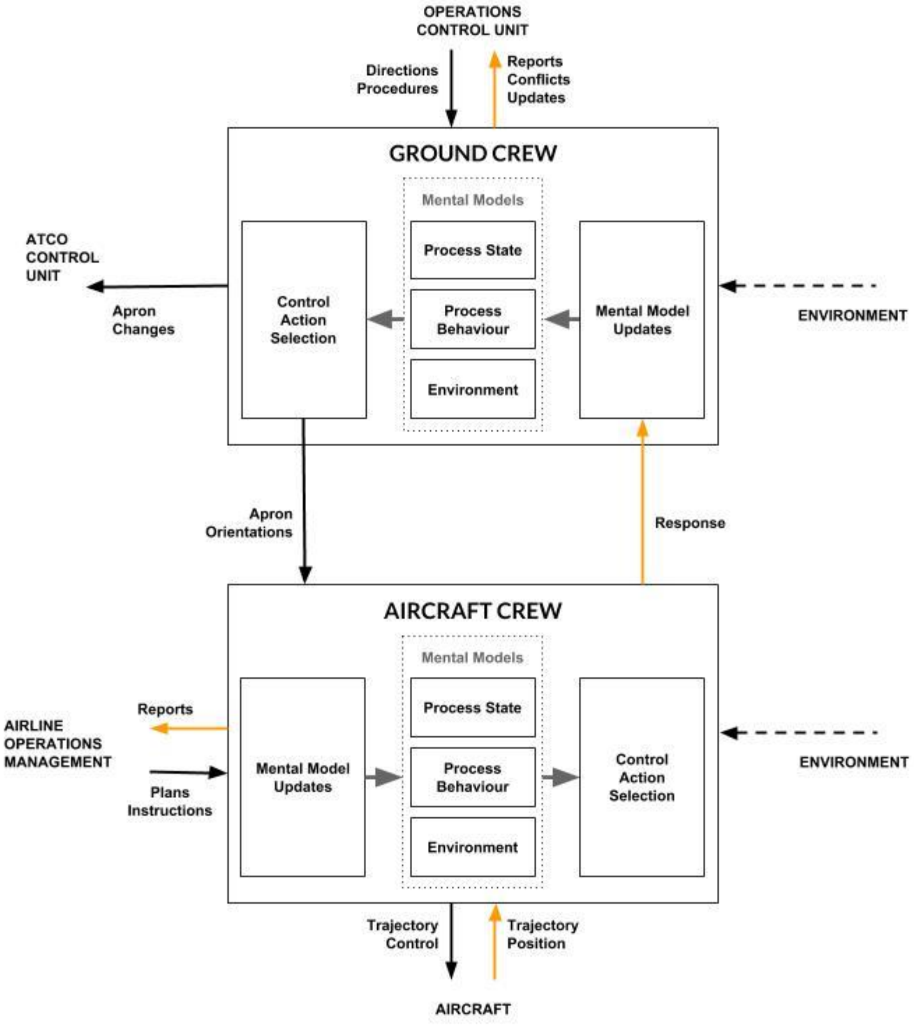
causal scenarios

S-1: Gnd Crew does not orient Aircrew to access Apron TBD when the alternatives are restricted/closed and hold position is not an option [UCA-1], **because the control algorithm specified by Infraero for the Gnd Crew have a flawed implementation**. This may cause its **decision making to be inadequate** and, consequently, its **behaviour, unsafe**. This could lead to aircraft *violating minimum separations*, *coming to close* to other parties, or even *loss of integrities* to any involved parties [H-1 to H-8].
(...)

24 CSs for UCA-1

496 CSs for GndCrew-CA-1

so far



1. CONTEXT & PRIOR WORK
2. WHAT & HOW
3. APPLYING STPA
4. **CONTRIBUTIONS**

contributions

Major problems identified for the airport case study
feedback, coordination, mental models, procedures, (...)

Results applicable to the airports with accidents
and extendable to other airports within the same cluster
less time and effort per analysis

Arguments to Airport Operator and Regulator
Visual and understandable method to show flaws
and how to deal with it from a top-to-bottom perspective

Many gains on applying STPA
better understanding of the system itself
human error properly addressed
easy process automation & verification

INFRAERO
AEROPORTOS

ANAC
Agência Nacional de Aviação Civil - Brasil

next steps on this research

Finish full analysis
by April 2018

Validate with Infraero
by May 2018

STPA for Airports: safety hazard analysis for aircraft operations in hub airports
paper to be published by May 2018

STAMP Approach Applied to Safety Hazard Analysis for Brazilian Airport Infrastructure
Master's dissertation to be presented due July 2018
and main paper to be published due September 2018

Questions?

STPA for Airports

safety hazard analysis for aircraft operations in hub airports

Idoaldo J Lima Claudio J P Alves Carlos H N Lahoz
Aeronautics Institute of Technology - ITA (Brazil)
idoaldolima@gmail.com

2018 MIT STAMP/STPA Workshop - March 29