"Unmanned Aerial Systems:
civilian applications
and technology challenges"

Politecnico di Torino,
EASN- European Aeronautical Science Network

9th and 10th November 2011
Sala Consiglio di Facoltà
Politecnico di Torino

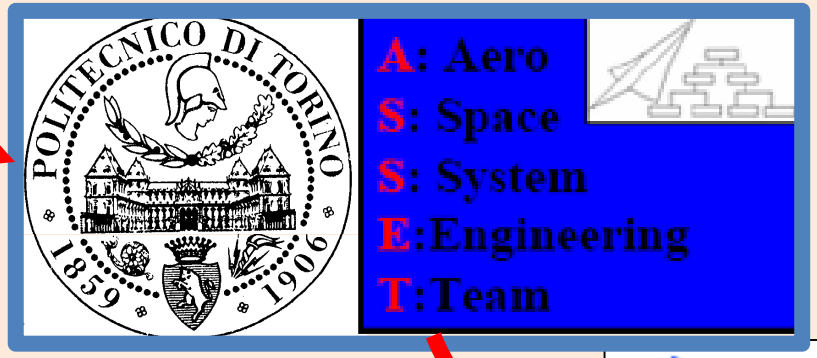
R.A.M.S. and LOGISTIC SUPPORT Studies in SMAT Program context

Sergio CHIESA (10-11-2011)

FONDO EUROPEO DI SVILUPPO REGIONALE
P.O.R. 2007 - 2013

R.A.M.S. and LOGISTIC SUPPORT Studies in SMAT Program context

Sergio CHIESA



In the field of complex Systems a concept acquired (but not always) is the relevance of the Support System

PRIMARY SYSTEM

MAINTENANCE | TRAINING

TOOLS | SPARES

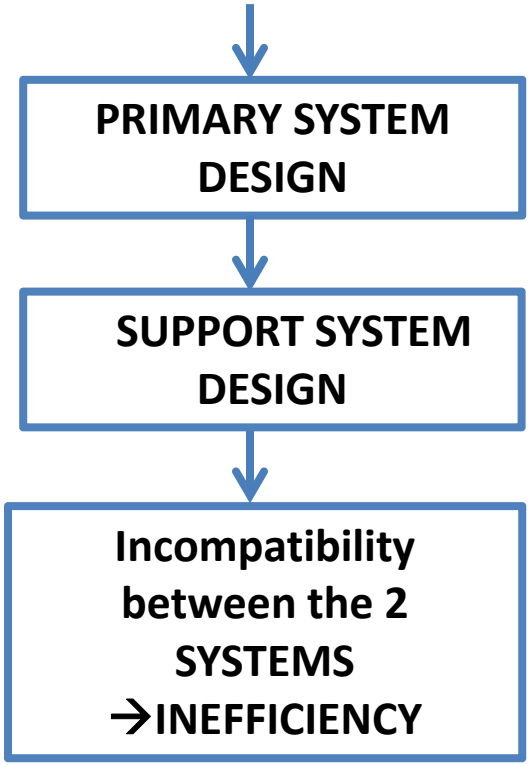
TECHN. PUBL. | TRANSPORTS

SUPPORT SYSTEM

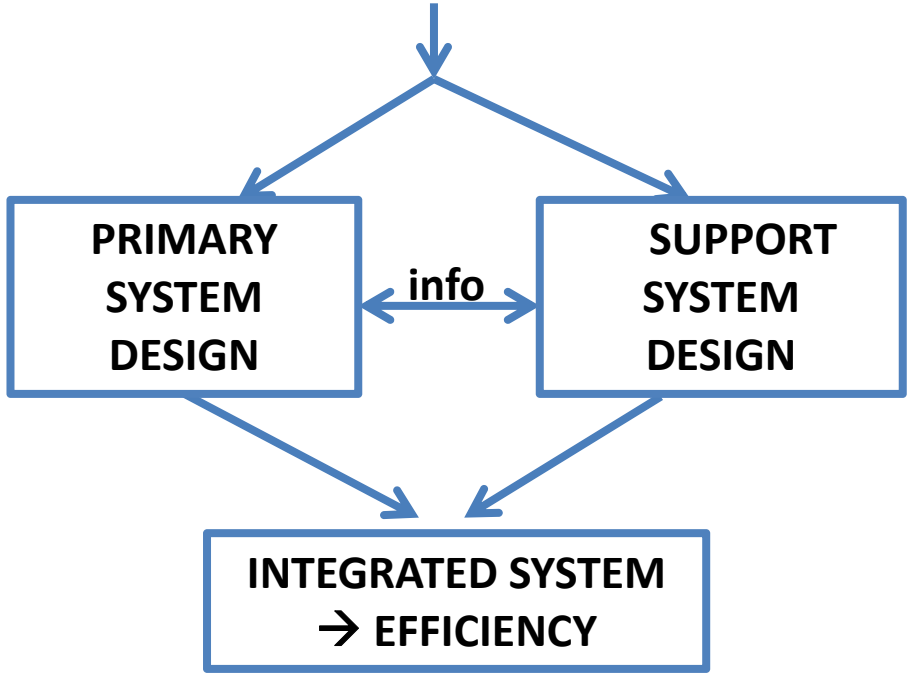
Without the SUPPORT SYSTEM, simply, the PRIMARY SYSTEM cannot run ! ! !

RELATED CONCEPT:

the SUPPORT SYSTEM has to be conceived and designed together with the PRIMARY SYSTEM

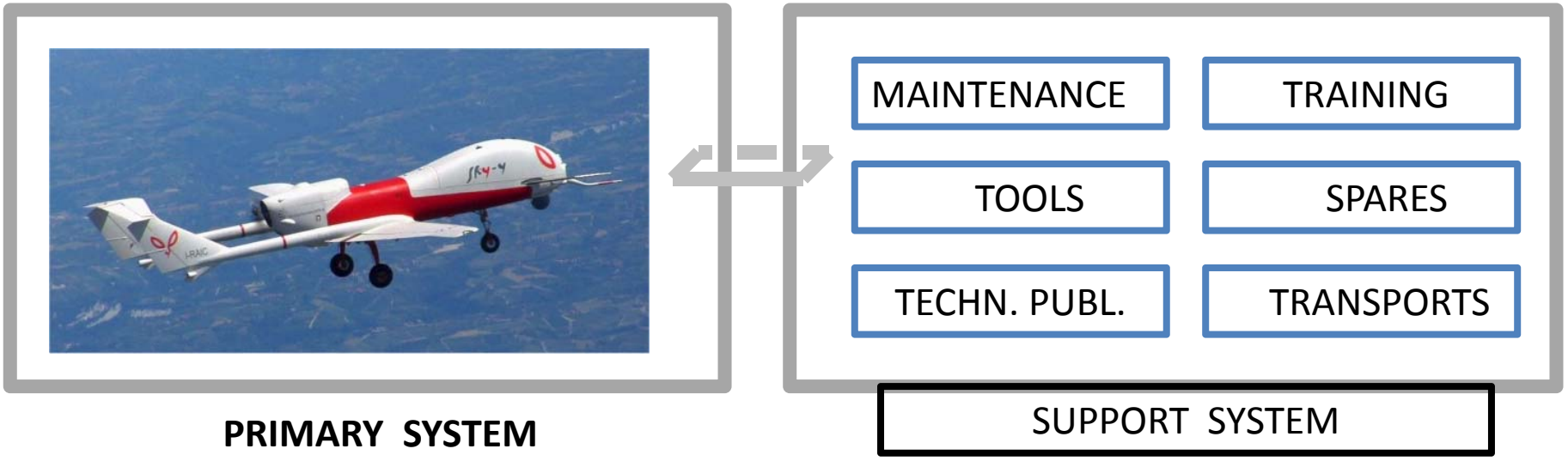


Obsolete concept



"INTEGRATED LOGISTIC SUPPORT" concept

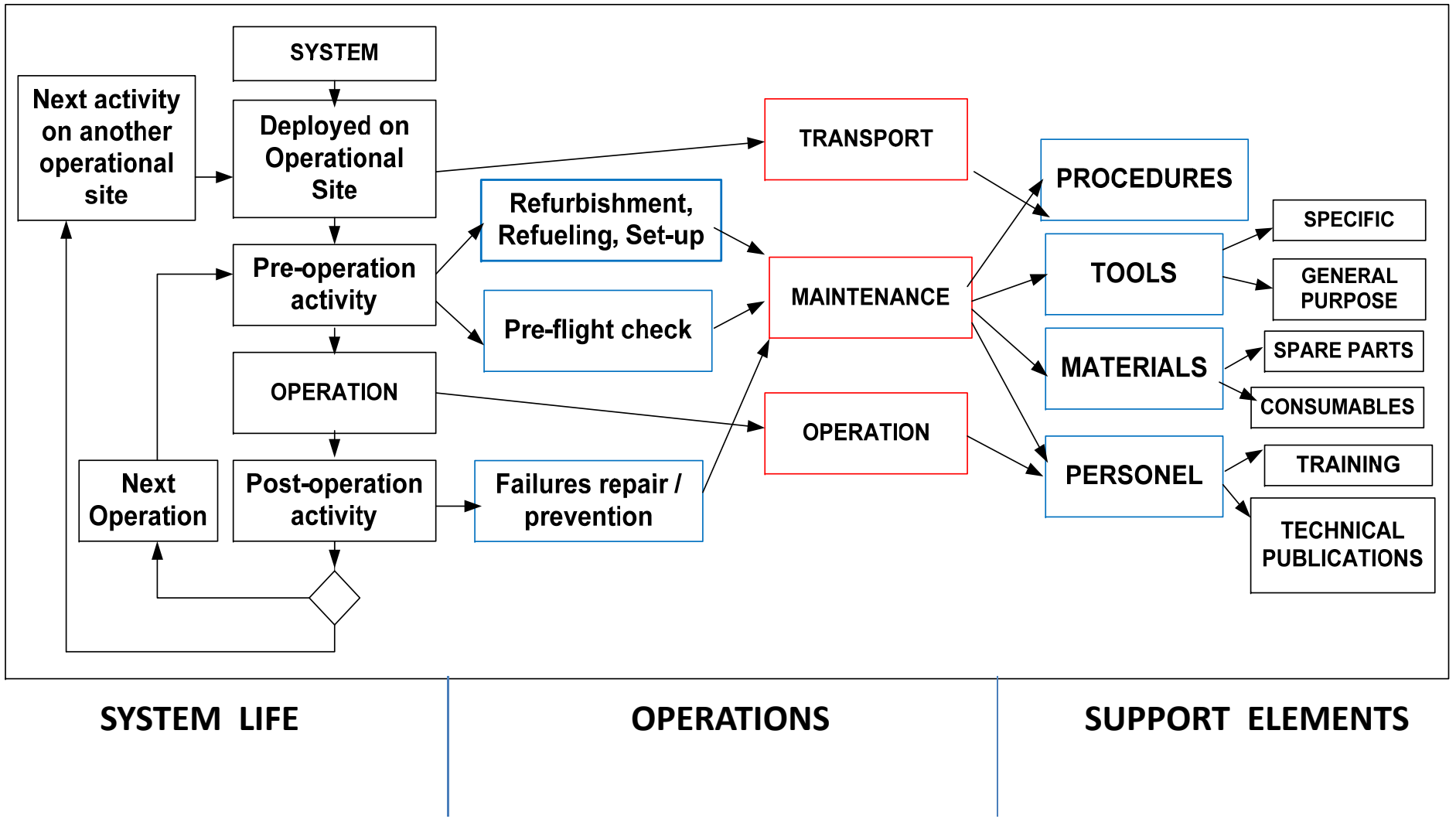
The U.A.S. are increasingly more important:



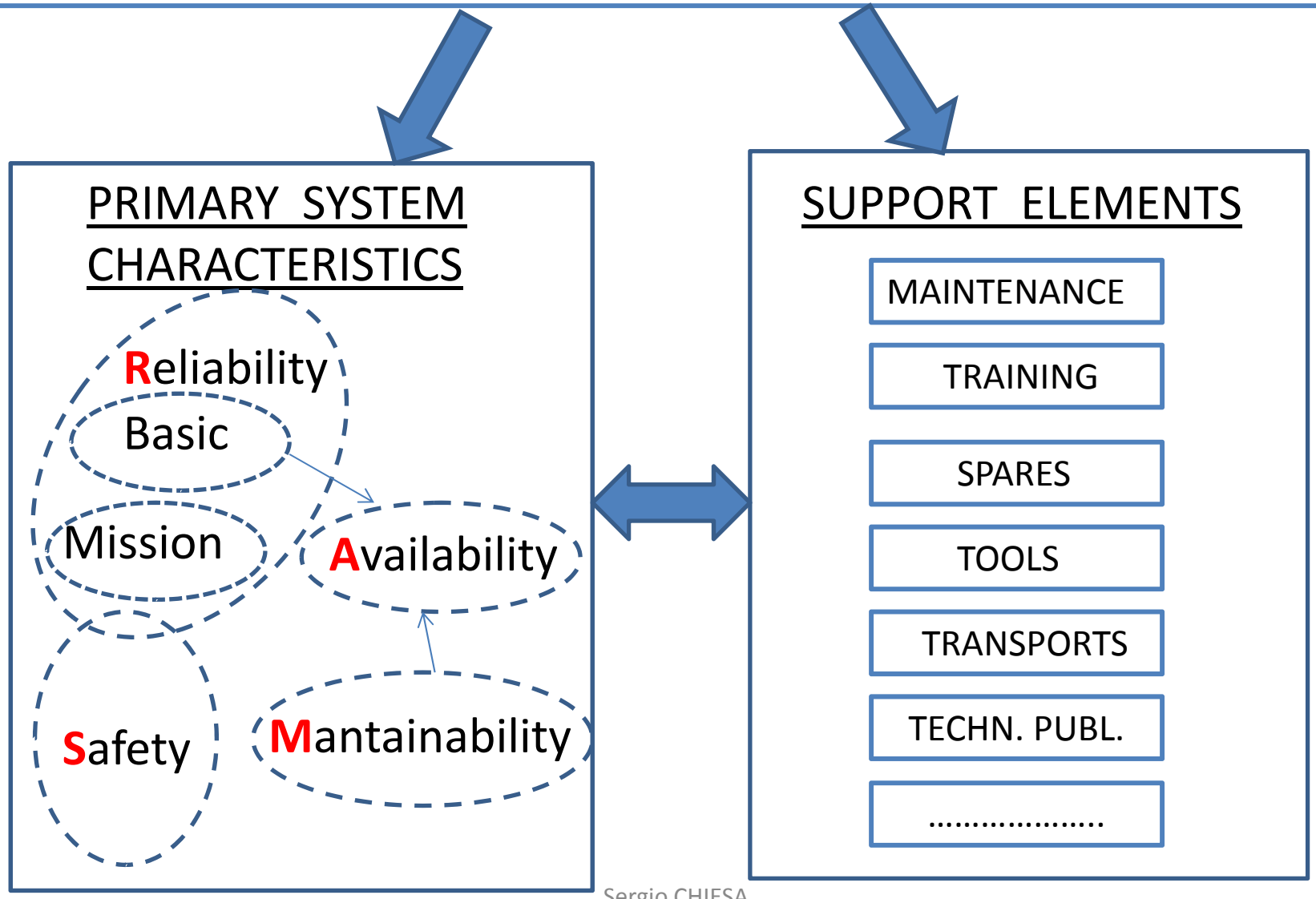
The U.A.S., at present in development phase, have to implement in optimal way the philosophy of

ILS - Integrated Logistic Support

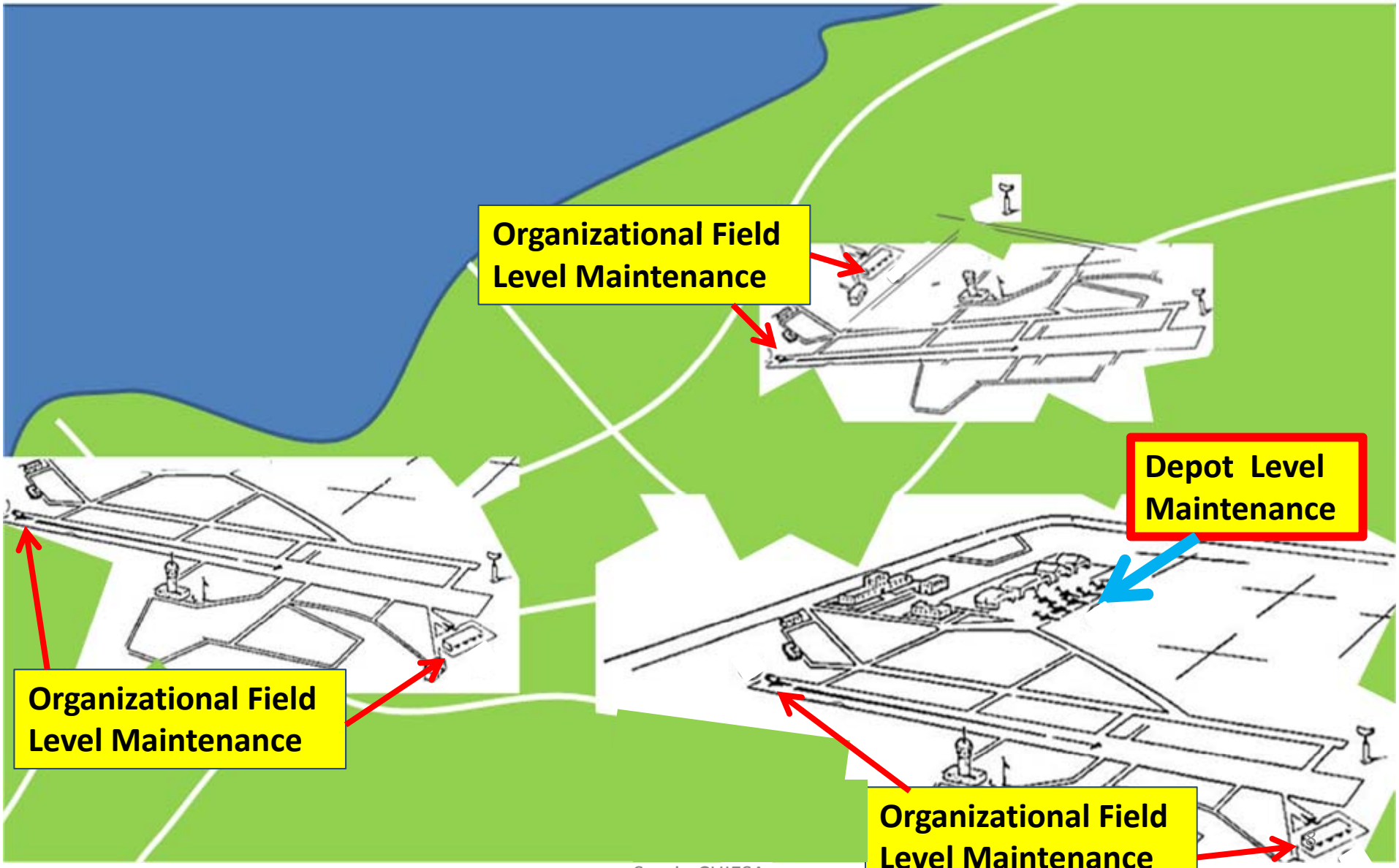
UAS Operations & Logistics



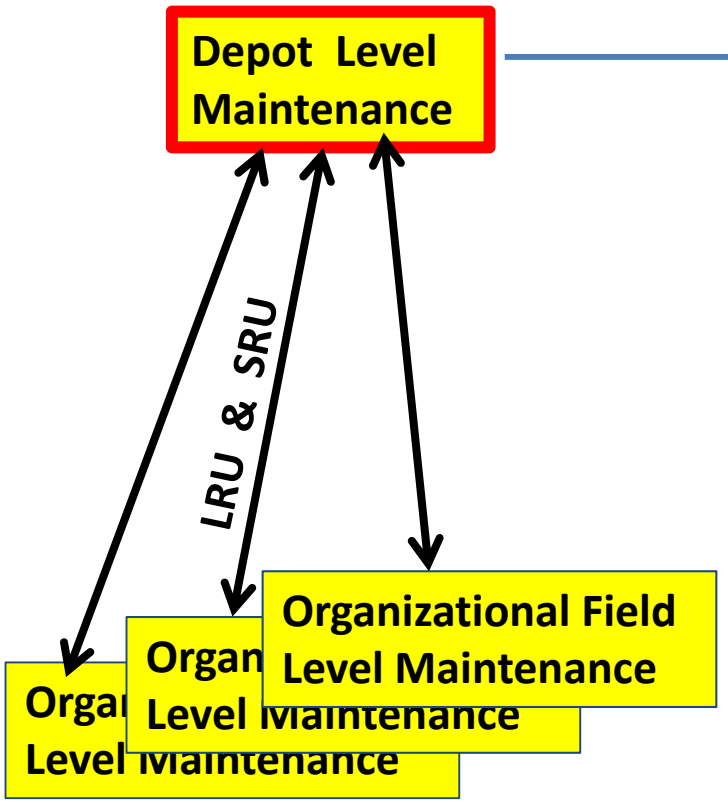
LOGISTIC SUPPORT ELEMENTS



OPERATIONAL-SUPPORT SCENARIO



SUPPORT SCENARIO



DEPOT-LEVEL MAINTENANCE Depot maintenance is the maintenance beyond the capabilities and/or facilities of the field. It will consist in verifying the SRU and LRU faults, isolation and repair of piece part(s), verification of repair, and return of serviceable units to inventory.

SHOP MAINTE--NANCE

On Equipment Maintenance Identifying and replacing the LRU faults that will be sent to Depot. Verification of repair.

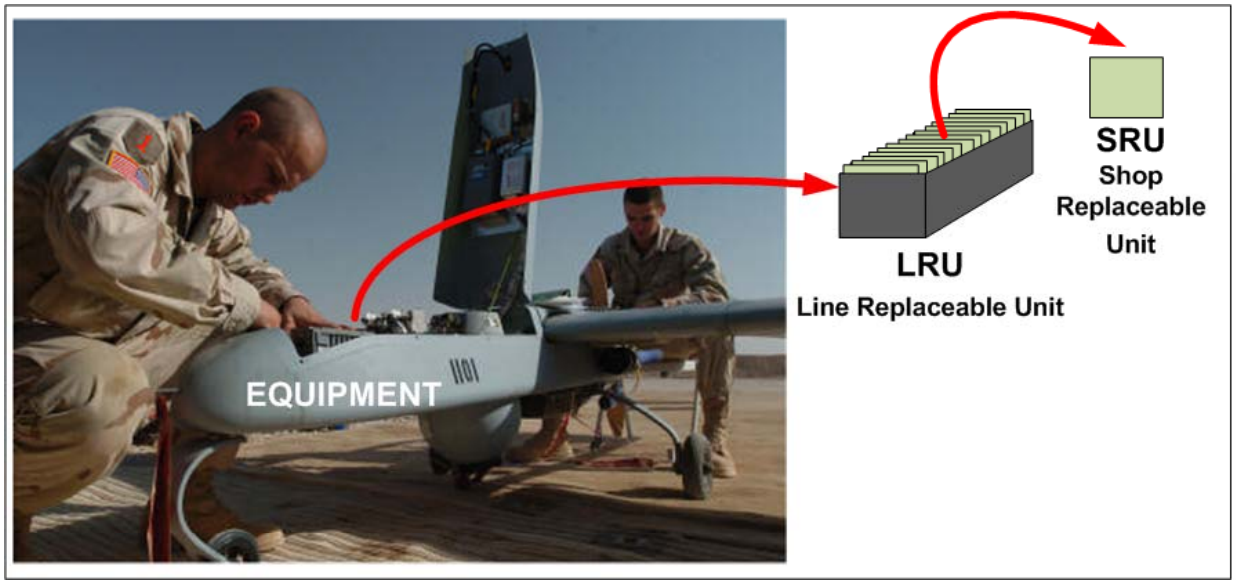
Off Equipment Maintenance Identifying and replacing (on LRU) the SRU faults (the ones for which it is possible) that will be sent to Depot. Verification of repair.

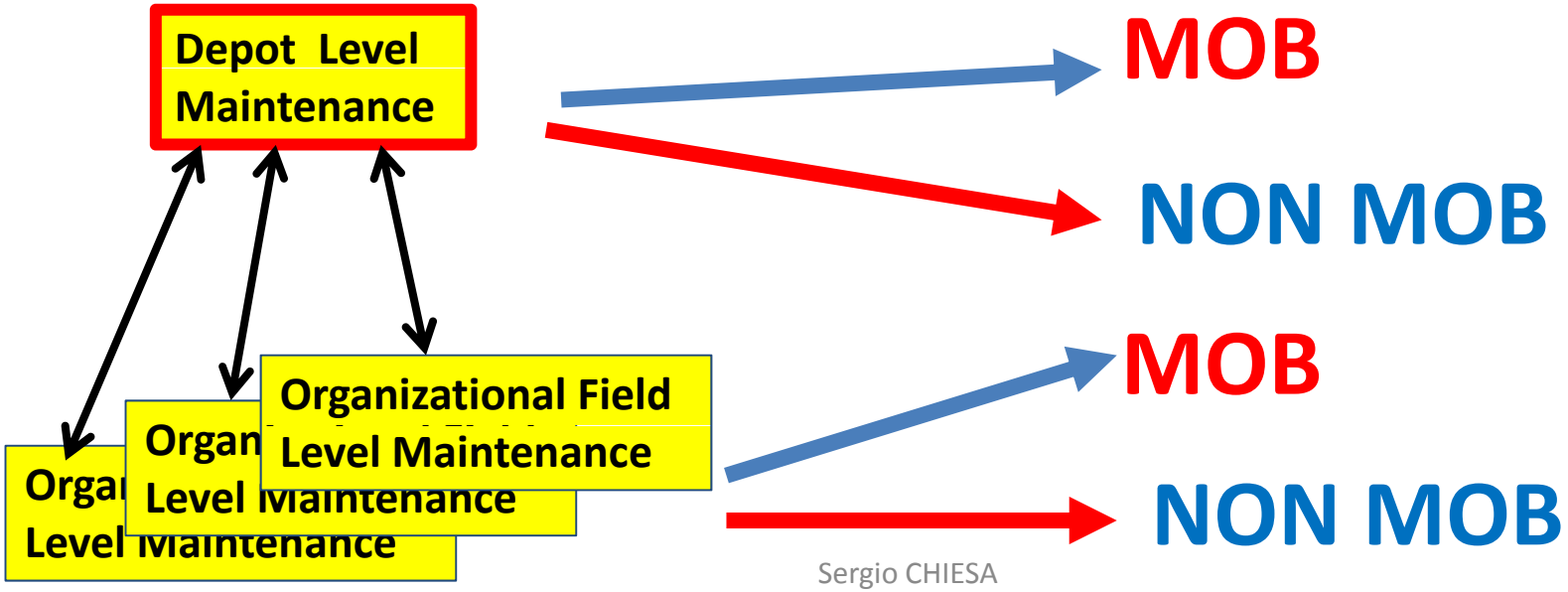
FLIGHT LINE MAINTE--NANCE

Maintenance Routine Refurbishment, Refit , Lubrication, Calibration, etc.

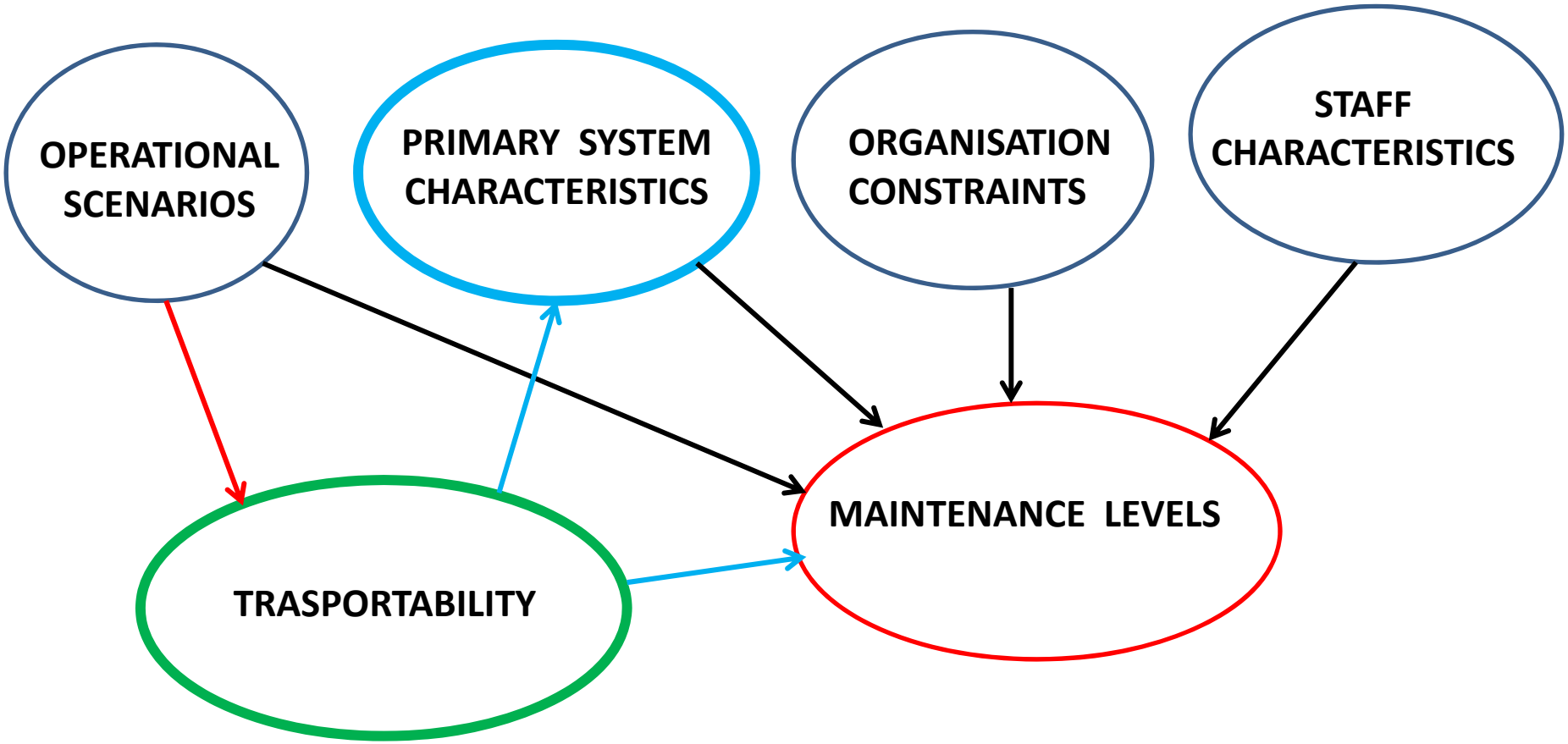
Inspections Pre/post flight, turn-around

SUPPORT SCENARIO

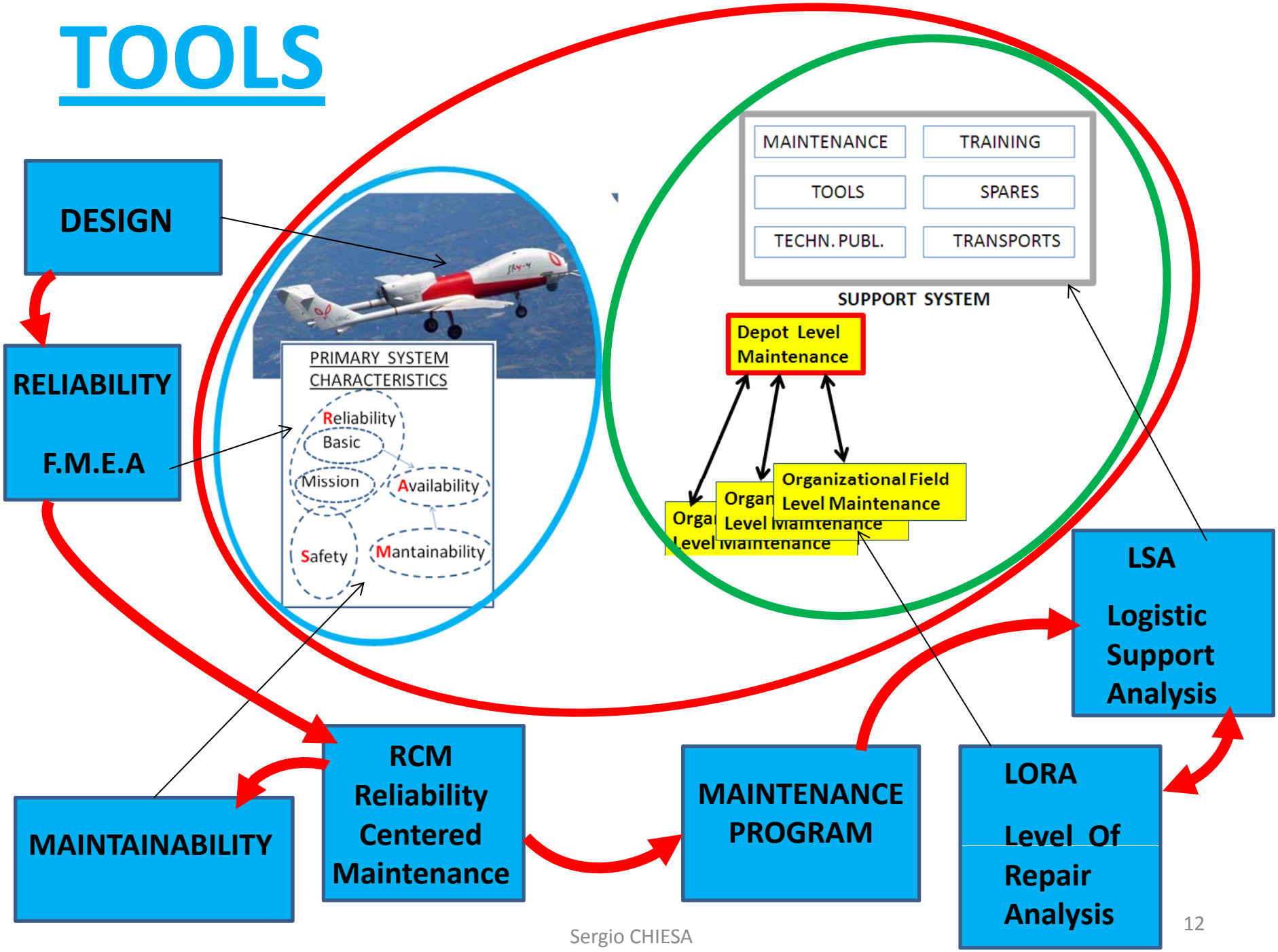




SUPPORT SCENARIO



TOOLS


DESIGN
RELIABILITY
F.M.E.A
MAINTAINABILITY
RCM
Reliability
Centered
Maintenance
MAINTENANCE
PROGRAM
LORA
Level Of
Repair
Analysis
LSA
Logistic
Support
Analysis
PRIMARY SYSTEM
CHARACTERISTICS
Reliability
Basic
Mission
Availability
Safety
Mantainability
MAINTENANCE
TRAINING
TOOLS
SPARES
TECHN. PUBL.
TRANSPORTS
SUPPORT SYSTEM
Depot Level
Maintenance
Organizational Field
Level Maintenance

TOOLS

Reliability Analysis - FMEA

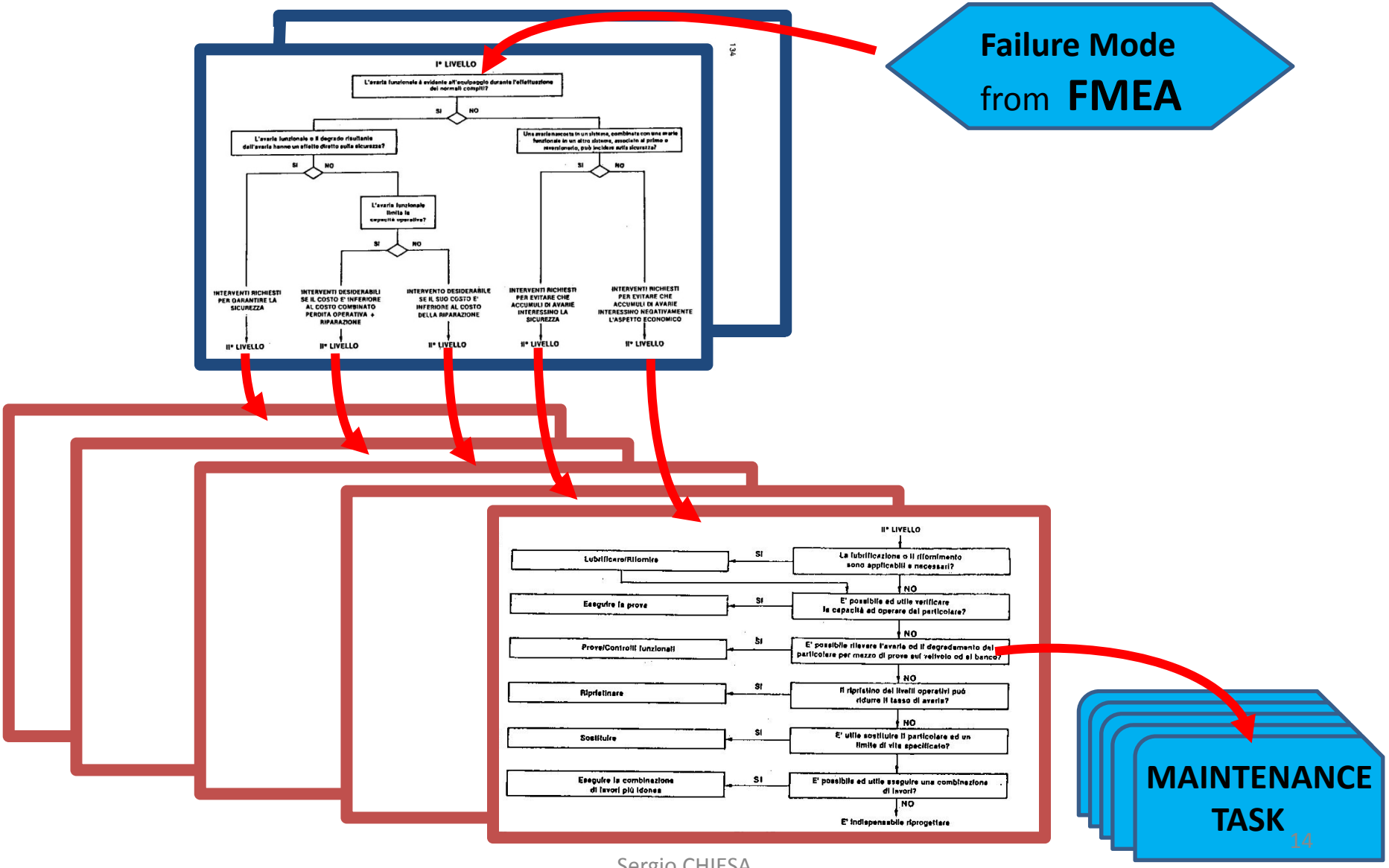
SYSTEM SAMPLE
SUBSYSTEM
SUBSYSTEM ELEMENT
PREPARED BY
APPROVED BY
DATE
REVISION
PAGE 1 OF 1

Item Identification	Function	Failure Mode	Failure Cause	Failure Effect on			Failure Detection Method	Remarks
				Component or Functional Assembly	Next Higher Assembly	System		
Switch	Initiates Motor Power Function	Fails to Open	Release Spring Failure Contacts Fused	None	Maintains Energy to Circuit Relay	Maintains Energy to Pwr Circuit Through Relay	Motor Continues to Run Smoke-Visual When Pwr Circuit Wire Overheats	
Battery #2 (Relay Circuit)	Provides Relay Voltage	Fails to Provide Adequate Power	Depleted Battery Plates Shorted	None Battery Gets Hot and Depletes	Fails to Operate Relay Circuit	Systems Fails to Operate	Motor Not Running	
Relay Relay Coil	Closes Relay Contacts When Energized	Coil Fails to Produce EMF	Coil Shorted or Open	Does Not Close Relay Contacts	Does Not Energize Pwr Circuit	System Fails to Operate	Motor Not Running	
Relay Contacts	Energizes and De-Energizes Pwr Circuit	Fails to Open	Contacts Fused	None	Maintains Energy to Motor	Overheated Pwr Circuit Wire if Motor is Shorted and Circuit Breaker Fails to Open	Motor Continues to Run Smoke-Visual	
Motor	Provides Desired Mechanical Event	Fails to Operate	Motor Shorted	Motor Overheats	High Current in Pwr Circuit	Overheated Pwr Circuit Wire if Circuit Breaker Fails to Open and Switch or Relay Fails	Smoke-Visual	
Circuit Breaker	Provides Pwr Circuit Fusing	Fails to Open	Contacts Fused Spring Failure	None	Maintains Pwr to Motor if Relay Contacts are Closed	Maintains Energy to Motor	Motor Continues to Run Smoke-Visual	
Battery #1 (Pwr Circuit)	Provides Motor Voltage	Fails to Provide Adequate Power	Depleted Battery Plates Shorted	None Battery Gets Hot and Depletes	None	System Fails to Operate	Motor Not Running	

Failure Mode from FMEA → **To RCM**

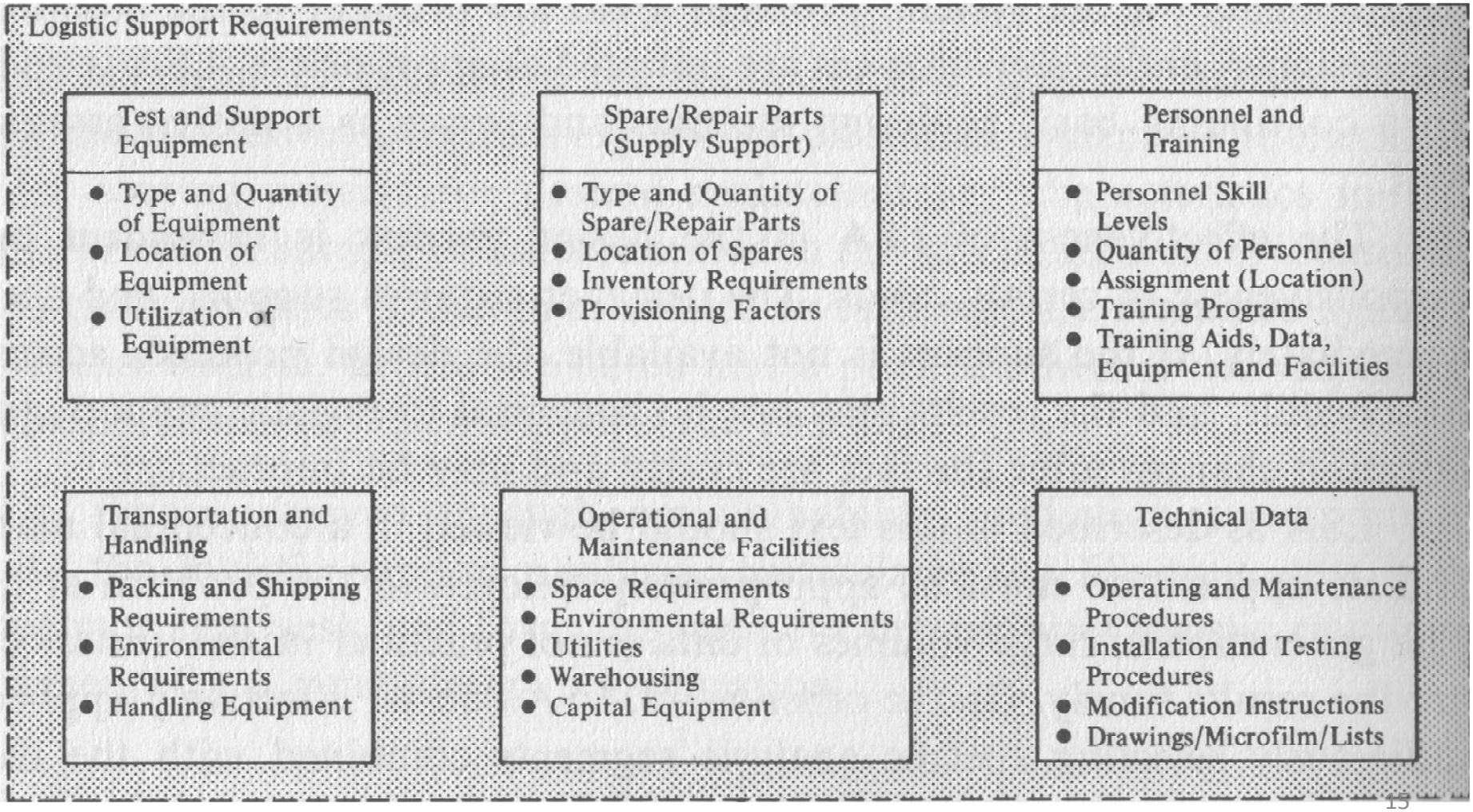
TOOLS

RCM – Reliability Centered Maintenance



TOOLS

LSA – Logistic Support Analysis



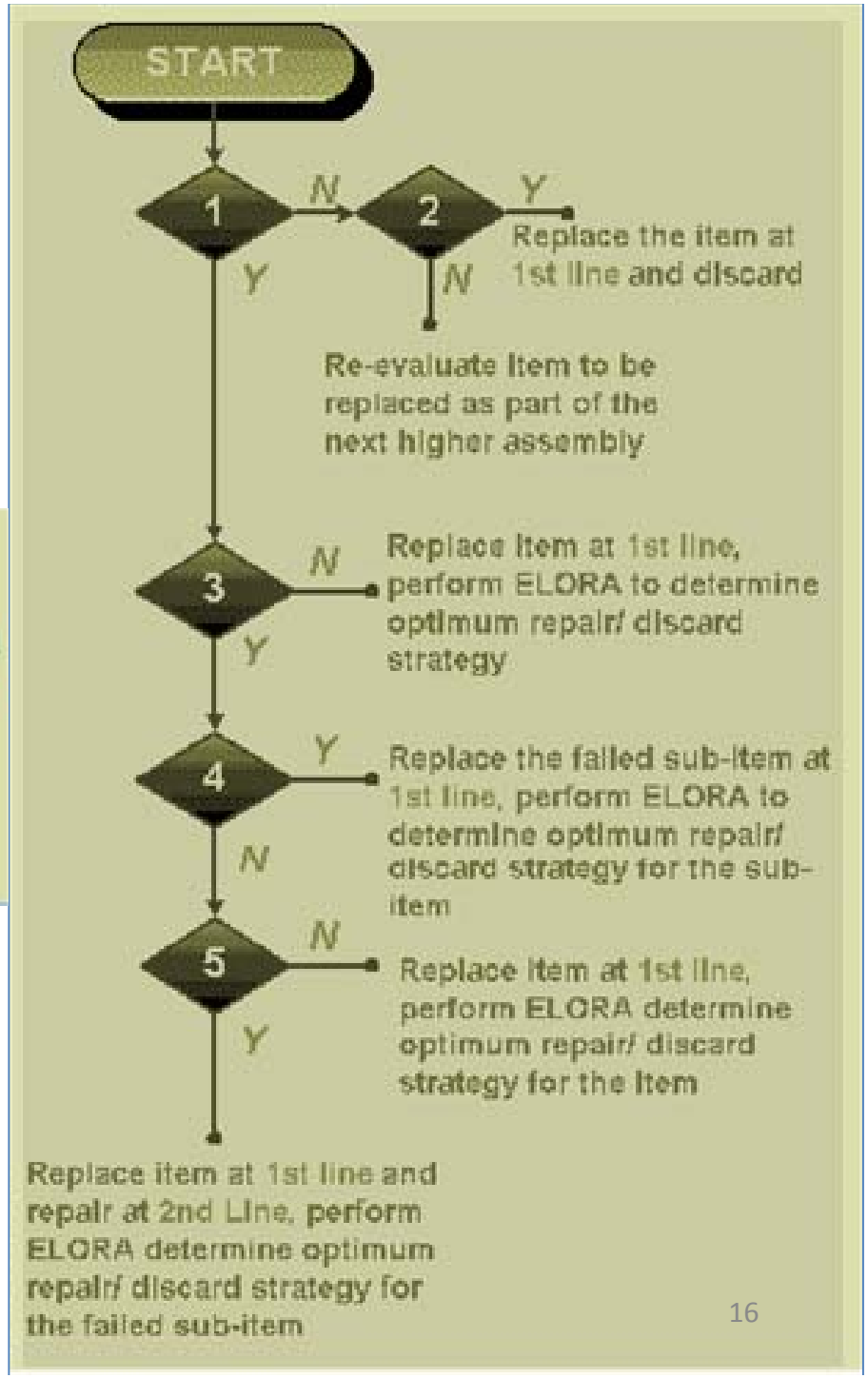
TOOLS

LORA – Level Of Repair Analysis

Questions

1. Is the design of the item such that repair is feasible?
2. Are the item's maintenance characteristics and installation such that a remove/replace strategy is feasible at first line?
3. Does the item have lower level subassemblies?
4. Does item's maintenance characteristics permit a replacement action of the sub-item?
5. Does the item's configuration consist of subassemblies from multiple vendors?

Economical Level Of Repair Analysis (ELORA)



Now the I.L.S. is well defined…

MIL-STD-1629A
24 NOVEMBER 1980
SUPERSEDING
MIL-STD-1629 (SHIPS)
1 NOVEMBER 1974
MIL-STD-2070 (AS)
12 JUNE 1977

MILITARY STANDARD

PROCEDURES FOR PERFORMING
A FAILURE MODE,
EFFECTS AND CRITICALITY ANALYSIS

MIL-STD-2173(AS)
21 JANUARY 1986
SUPERSEDING
MIL-HDBK-266(AS)
14 AUGUST 1981

MILITARY STANDARD

RELIABILITY-CENTERED MAINTENANCE
REQUIREMENTS FOR NAVAL AIRCRAFT,
WEAPONS SYSTEMS AND SUPPORT EQUIPMENT

MIL-STD-1388-2B
28 MARCH 1991
NOTICE 1
21 JANUARY 93
SUPERSEDING
MIL-STD1388-2A
10 JULY 84

MILITARY STANDARD

DOD REQUIREMENTS FOR A
LOGISTIC SUPPORT ANALYSIS RECORD

MIL-HDBK-470A
4 AUGUST 1997
SUPERSEDING
MIL-HDBK-470
12 JUNE 1995
MIL-HDBK-471
12 JUNE 1995

DEPARTMENT OF DEFENSE
HANDBOOK

DESIGNING AND DEVELOPING MAINTAINABLE
PRODUCTS AND SYSTEMS

MIL-STD-1390D
19 JANUARY 1993
SUPERSEDING
MIL-STD-1390C(NAVY)
8 JULY 1988

MILITARY STANDARD

LEVEL OF REPAIR ANALYSIS

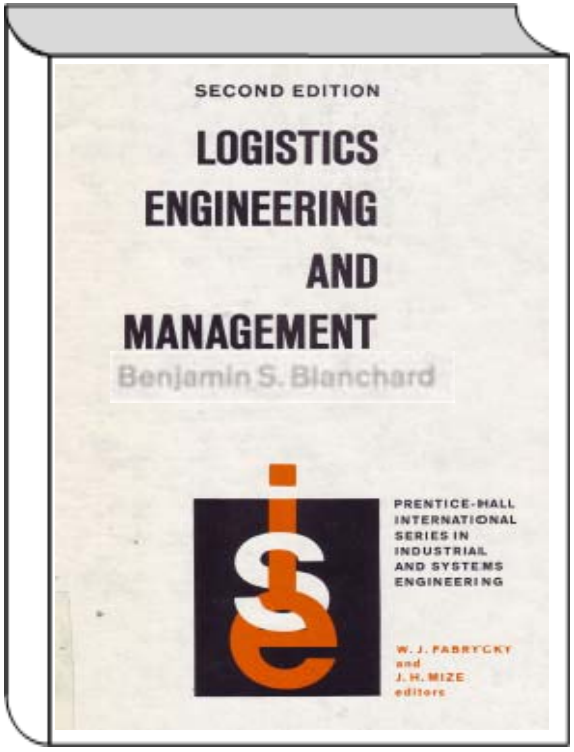
(LORA)

MIL-STD-1369(EC)
31 MARCH 1971

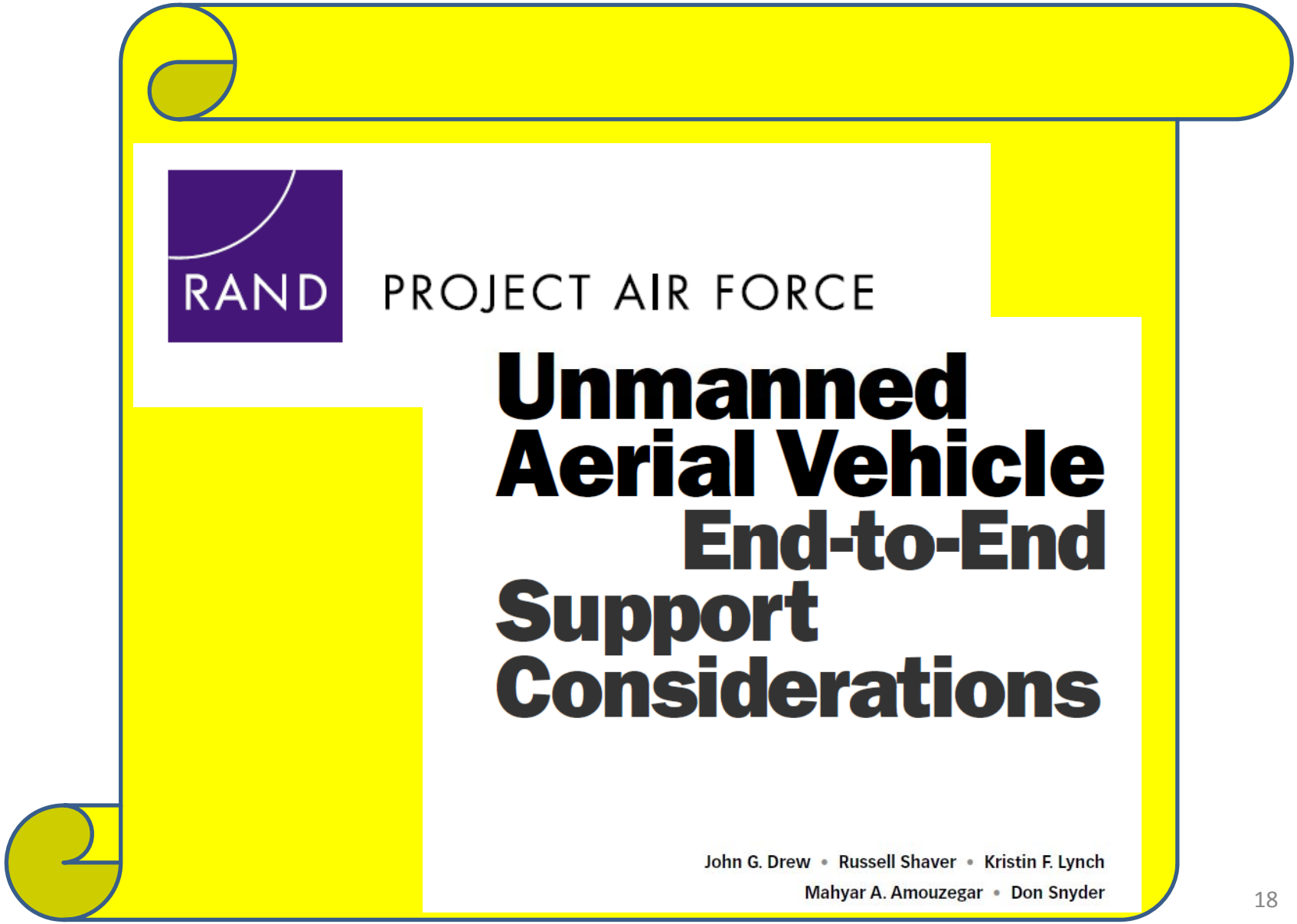
MILITARY STANDARD

INTEGRATED LOGISTIC SUPPORT
PROGRAM REQUIREMENTS

With a lot of appreciable scientific Text Books, eg:



…this is the THEORY…but…



Historically, logisticians have not always been able to effectively articulate the effects of rapid design and procurement realities on support, which ultimately affect operations. Rapid acquisition processes do not allow sufficient time for developing technical data and fully integrating training requirements. In spite of these circum-

Currently, traditional logistics requirement determination and rapid acquisition are not integrated. However, there may be other ways to address this integration. If an SDD or LSA is not completed, some of the necessary data could be estimated. Alternatively, implied values could be used to determine support requirements. If exact values are not available, a range of values could be explored to estimate support requirements. We will explore this concept further in Chapter Four.

CHAPTER FOUR

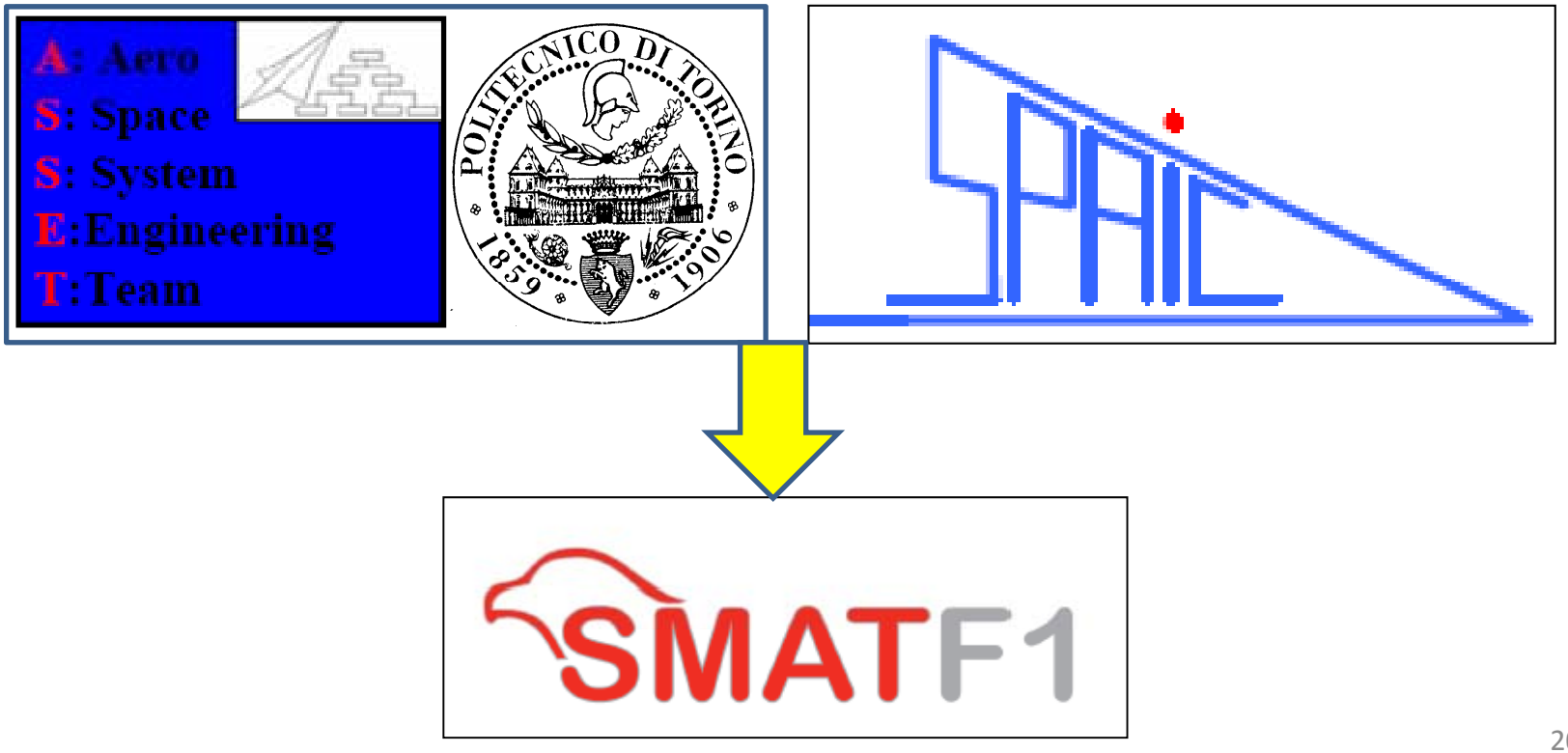
The Logistics Implications Capabilities Assessment Model

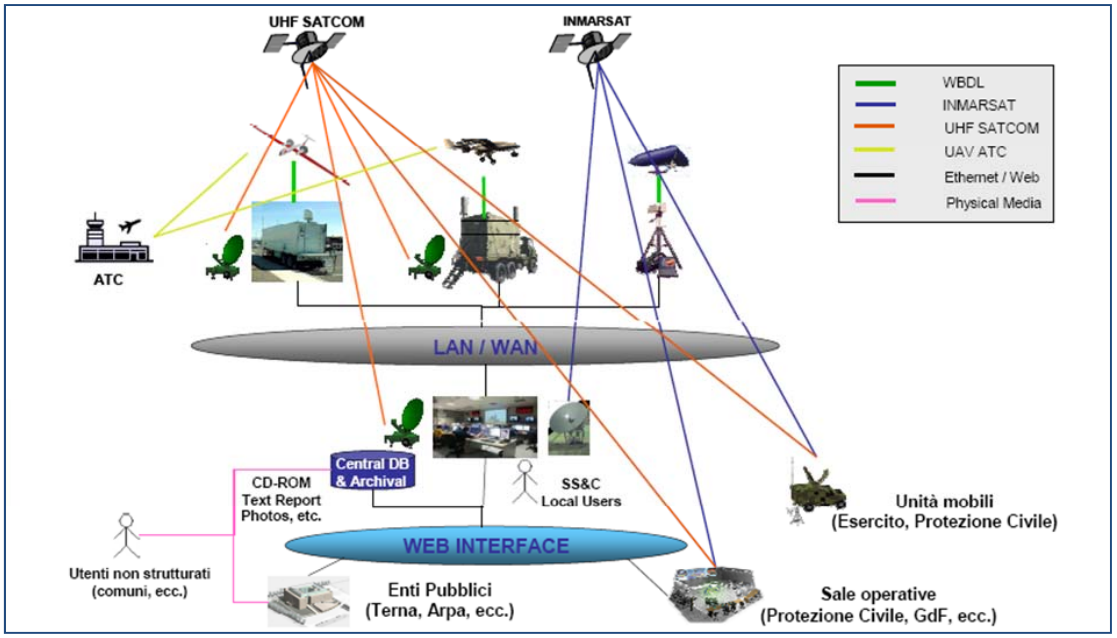
A key metric in assessing the effectiveness of support and acquisition policies is the capability of the UAV fleet to provide orbital coverage. Lack of thorough historical data, combined with other support and operational issues, highlighted the need for a comprehensive simulation model. We developed an Extend-based simulation model, LICAM, to evaluate the trade-offs between various operational and support parameters.[1] LICAM is a discrete-event stochastic simulation model that translates various high-level logistics parameters, such as fleet size, break rates, and repair rates, into operationally measured metrics, including the percentage of time a vehicle would provide coverage over a specific target area.

The opportunity of developing realistic SIMULATION MODELS of complex Systems, integrated with their Logistic Support is underlined

Such models are powerful tools for the DECISION MAKING, during the development of great, potentially critical, Integrated Systems

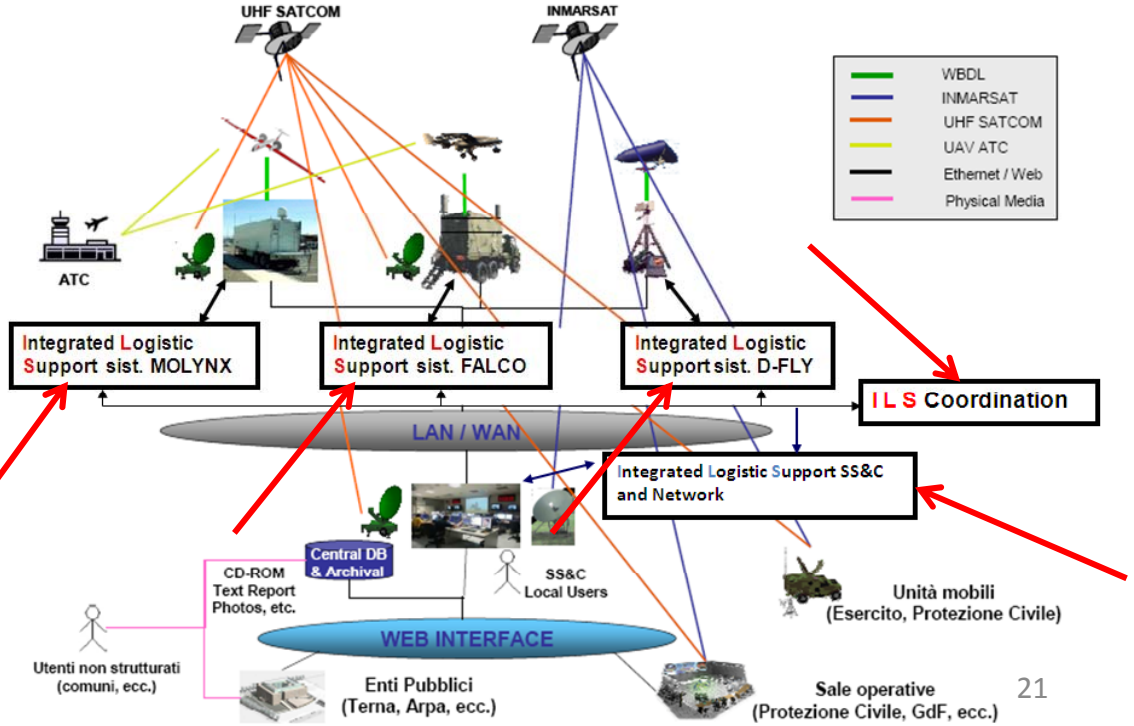
The development of a Logistic-Operative simulation model of the UAVs fleet foreseen by SMAT Project has been carried out by AeroSpace System Engineering Team (ASSET) of the POLITECNICO di TORINO, with the cooperation of S.P.A.I.C.srl.



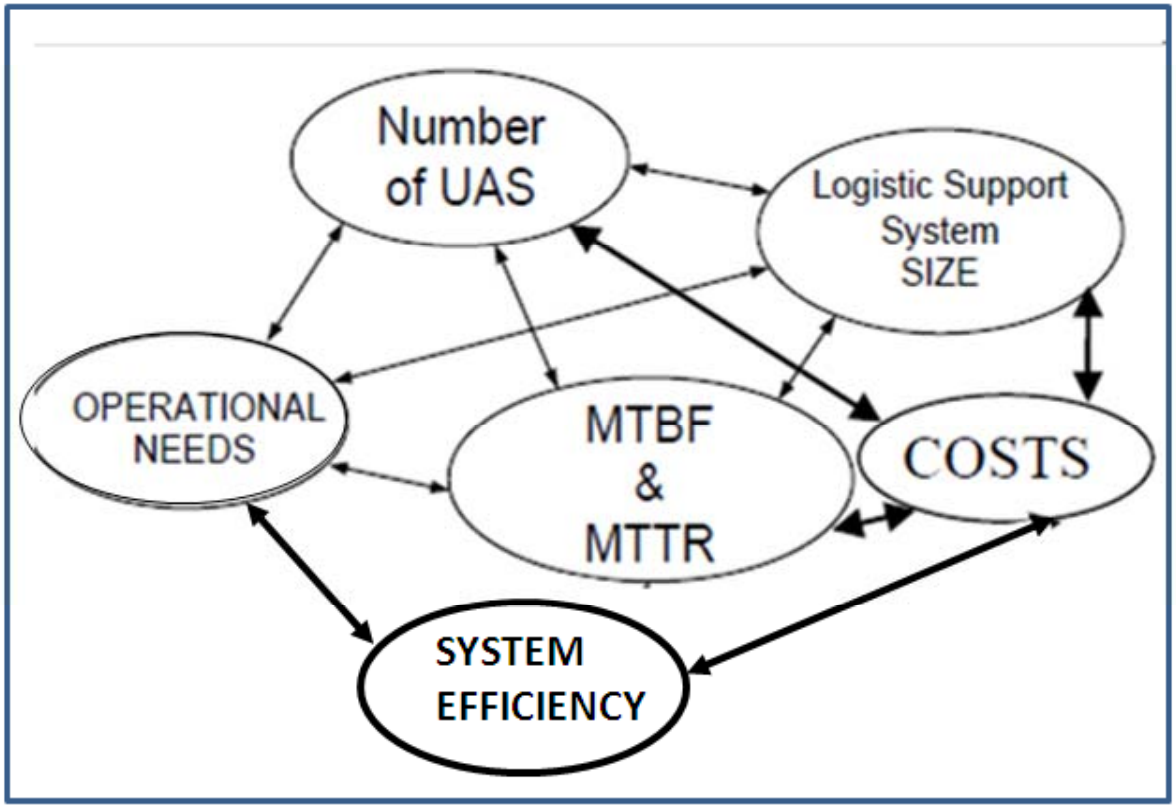


SMAT is a complex System Of Systems

The complexity increases very much if we consider the Integrated Logistc Support, both for the three UAS (fleet and Ground Station) and for the SSC (Supervision and Control Station)



The optimization of the set is difficult, particularly considering the complexity, but really more extended yet, because of the different classes of UAS, and their INTEGRATED LOGISTIC SUPPORT.

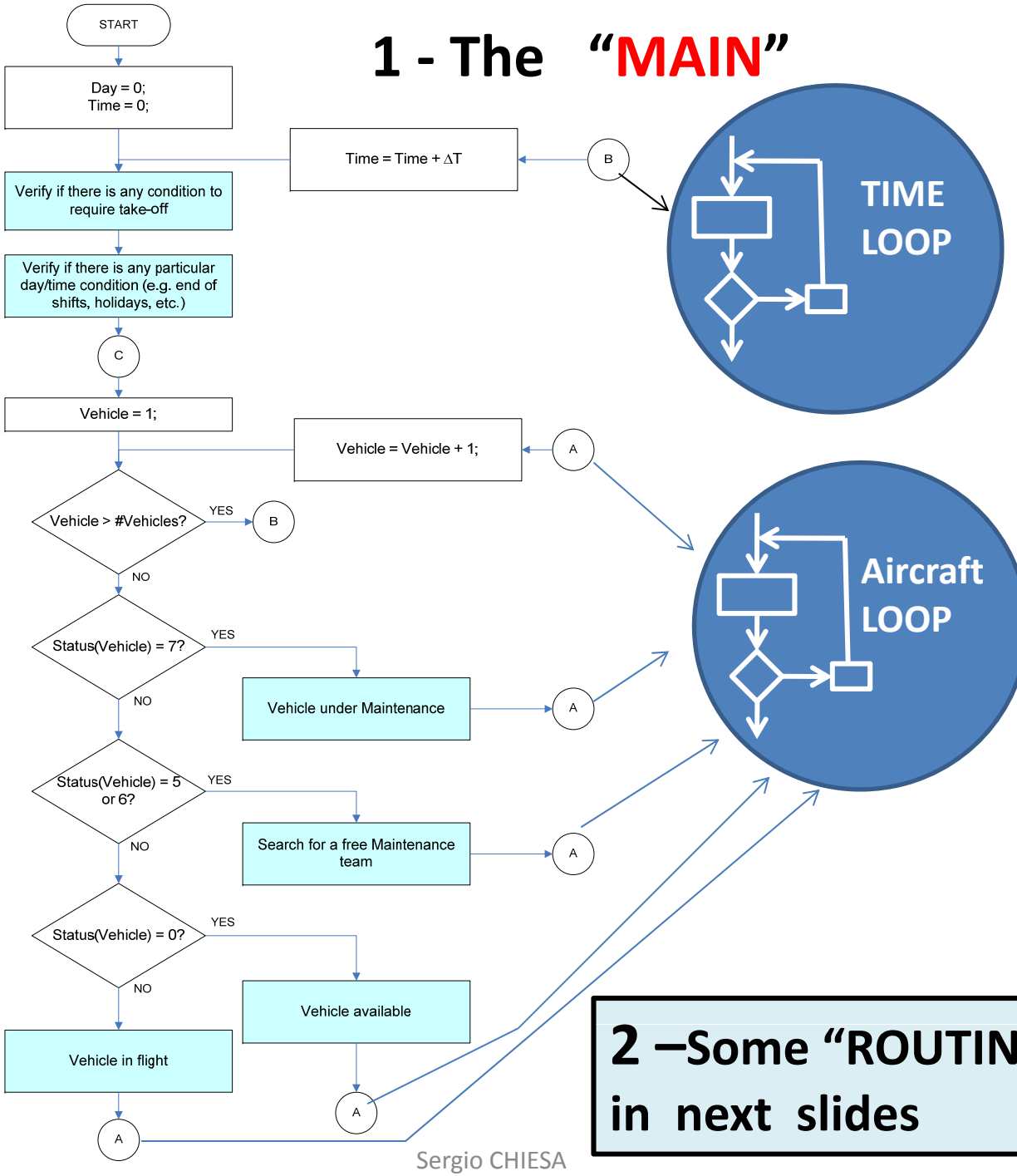


The way to solve the problem is the development of an efficiency simulation of the whole system based on Monte-Carlo method, topic on which the Research Group has achieved great experiences in the past.

Synthetic presentation of the SIMULATION MODEL

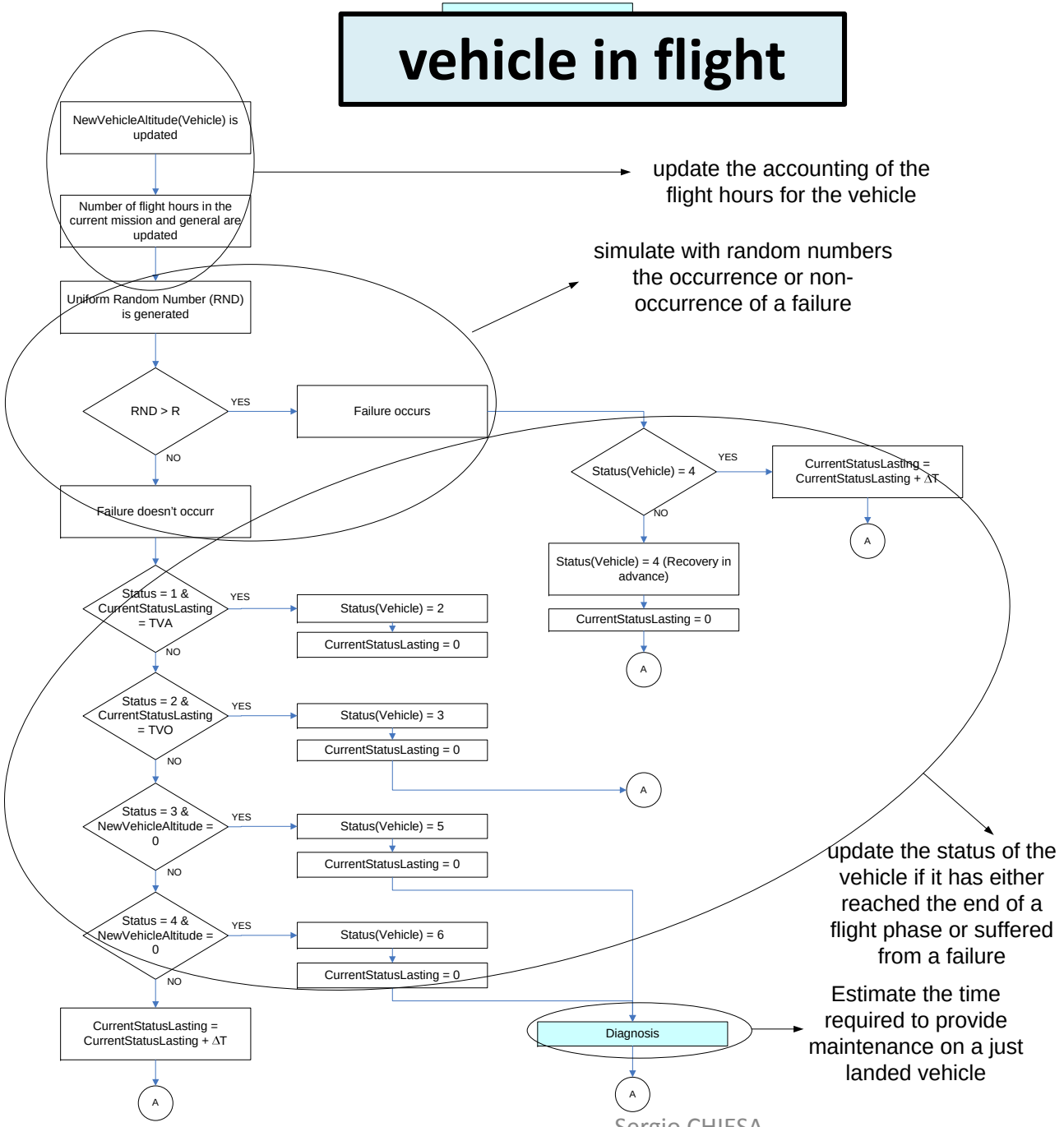
In the figure is reported a simplyfied version without the “LOOP of BASES”, that is able to study a fleet operative on only one base (i.e. the MALE)

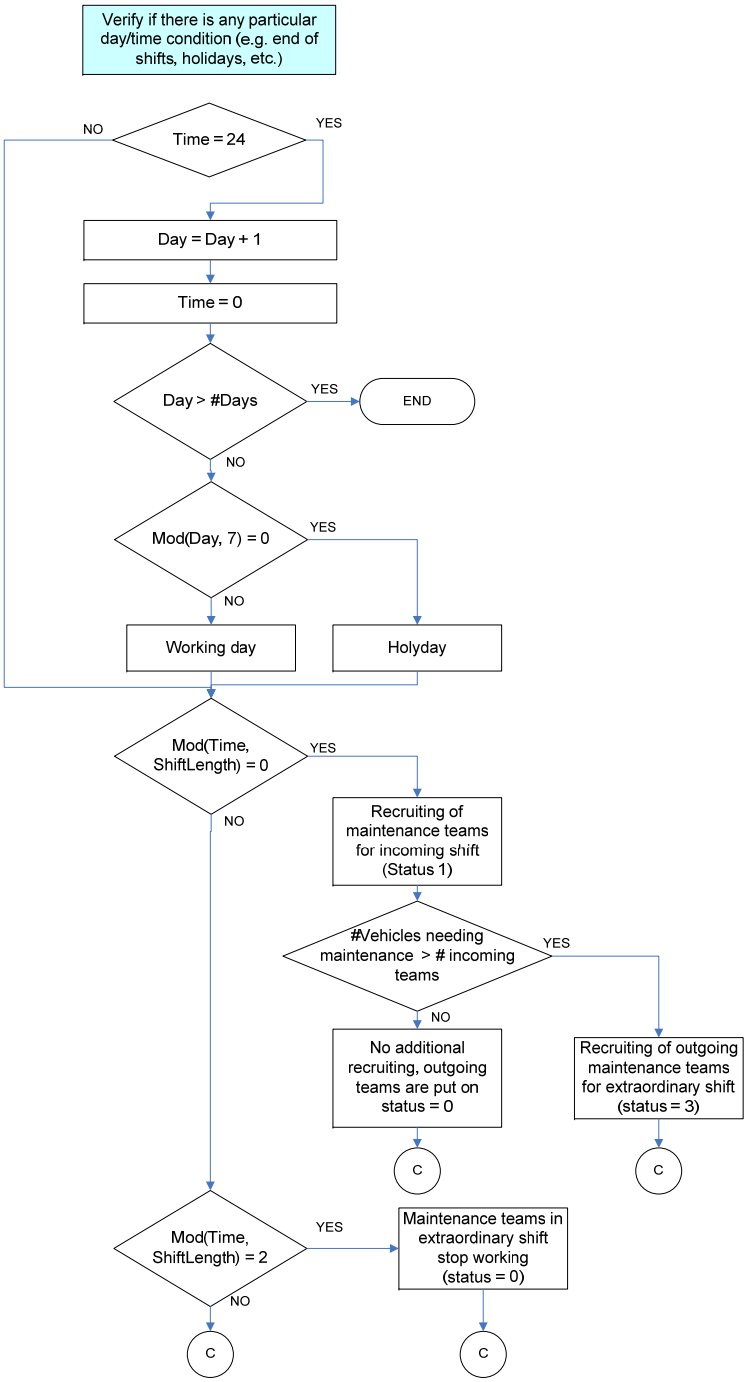
1 - The “MAIN”

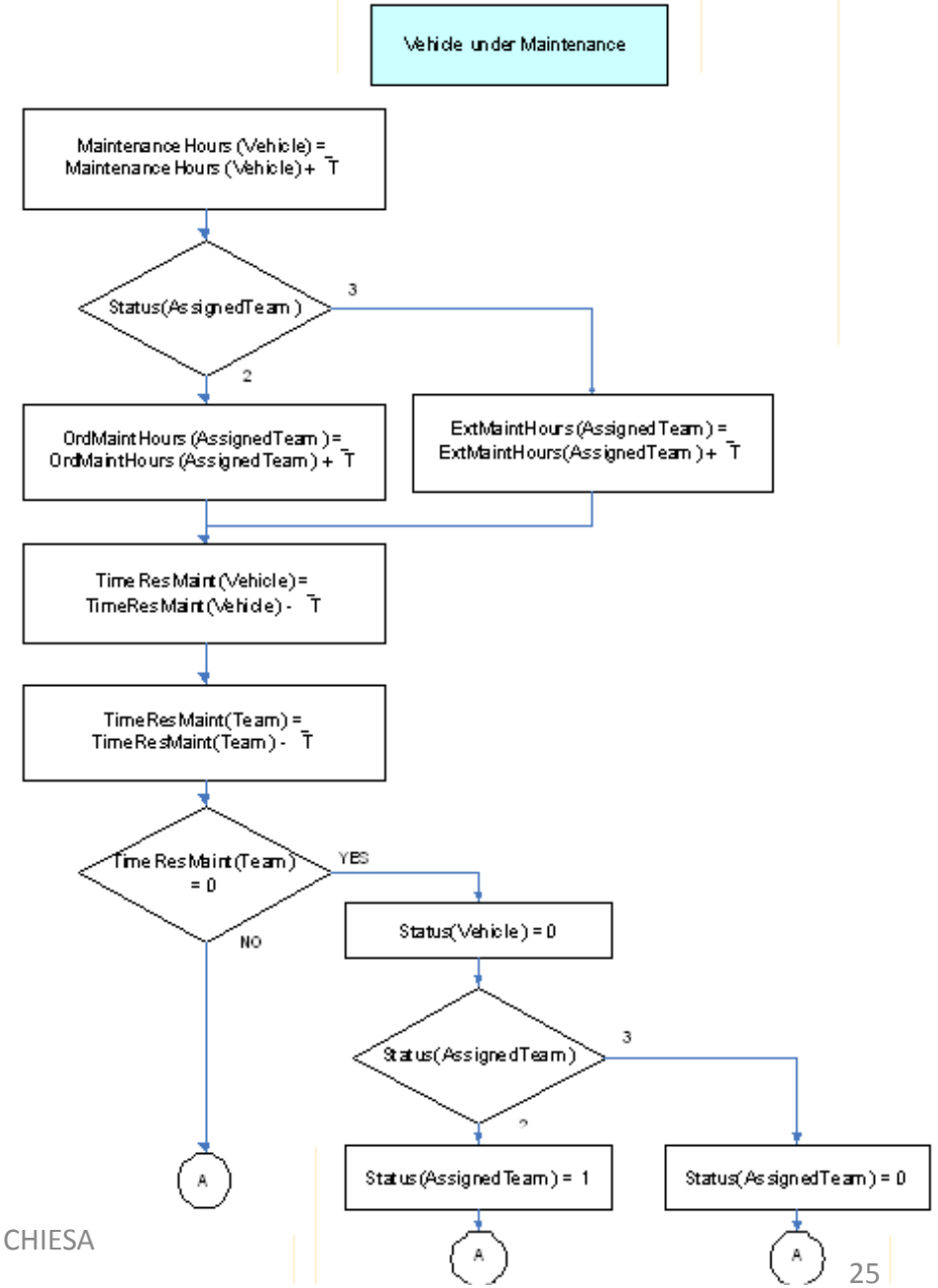


2 –Some “ROUTINES” in next slides

vehicle in flight

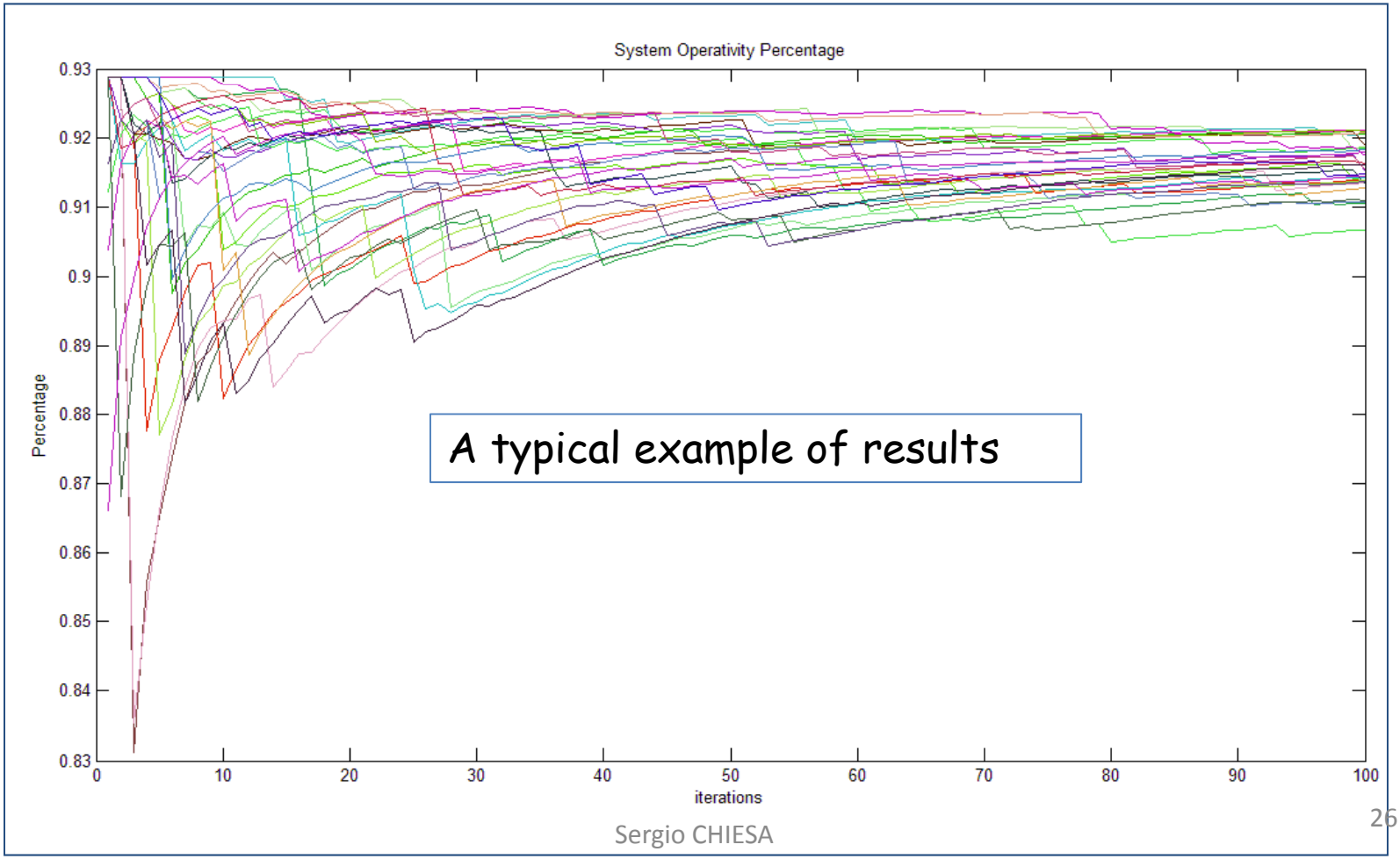



Verify if there is any particular day/time condition (e.g. end of shifts, holidays, etc.)
Time = 24
NO
YES
Day = Day + 1
Time = 0
Day > #Days
YES
END
NO
Mod(Day, 7) = 0
YES
NO
Working day
Holyday
Mod(Time, ShiftLength) = 0
YES
NO
Recruiting of maintenance teams for incoming shift (Status 1)
#Vehicles needing maintenance > # incoming teams
YES
NO
No additional recruiting, outgoing teams are put on status = 0
Recruiting of outgoing maintenance teams for extraordinary shift (status = 3)
C
C
Mod(Time, ShiftLength) = 2
YES
NO
Maintenance teams in extraordinary shift stop working (status = 0)
C
C


Vehicle under Maintenance
Maintenance Hours (Vehicle) = Maintenance Hours (Vehicle) + T
Status(AssignedTeam)
3
2
OrdMaintHours (AssignedTeam) = OrdMaintHours (AssignedTeam) + T
ExtMaintHours (AssignedTeam) = ExtMaintHours(AssignedTeam) + T
TimeResMaint(Vehicle) = TimeResMaint(Vehicle) - T
TimeResMaint(Team) = TimeResMaint(Team) - T
TimeResMaint(Team) = 0
YES
NO
Status(Vehicle) = 0
Status(AssignedTeam)
3
2
A
Status(AssignedTeam) = 1
Status(AssignedTeam) = 0
A
A

SIMULATION RESULTS

A preliminary set of Monte-Carlo simulations was performed to check the effectiveness of the algorithm. This set included **30 runs** with **100 iterations each**, with each iteration lasting for **10 simulated days**. Repeating several runs of Monte-Carlo simulation can provide an approximate of statistical distribution of the interest parameter.



CONCLUSIONS

- **The model is very complex but this is acceptable considering the complexity of real System**
- **The final version is comprehensive of the "Bases Loop", with a lot of complications:** ***1) two levels of Maintenance only in Main Base vs in all Bases; 2) transfer of AC (efficient or not efficient, in flight or by terrestrial transports) between the bases***
- **Preliminary tests on final version seem to be good**
- **Future improvements:** ***1) statistical models of service demand on the basis of data from ProCiv; 2) Meteo conditions on different bases conditioning the take-off. 3) More detailed description of UAVs taking into account different technologycal ambitous of on board systems, each one with its particularities 4) Simulation of the second Maintenance Level, following iter of LRUs and SRUs removed at first level and sent to Depot.***

We hope to have possibility of performing this work in SMAT f2 !

Thank you for your attention !

Any questions ?