Project ‘CTAAS’
Controlled Time of Arrival for Airports System

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Agenda

1. Introduction
2. Stakeholder Identification
3. CTAAS CONOPS
4. Model Description
5. Business Case
6. Conclusion
7. Questions & Answers

Introduction

- Existing National Airspace System
  – Based on 1950s concepts and 1960s technology
  – Unable to effectively accommodate increasing traffic
  – Inherent inefficiencies drive up costs and reduces air traffic throughput
- CTAAS is a system that:
  – Integrates and utilizes new technologies
  – Directs flight arrival information to inbound aircraft
  – Reduce the arrival flow variance at busy airports

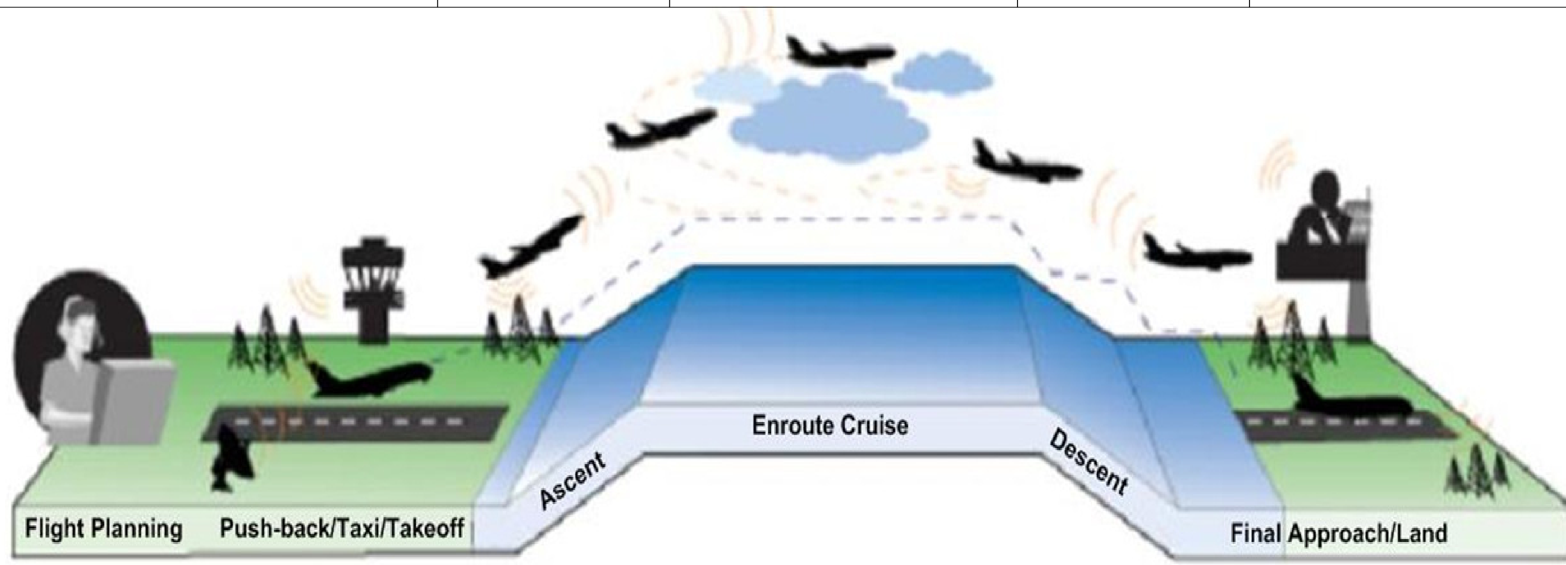
- Integration of these technologies will expand runway traffic capacity and yield cost savings to the industry

CTAAS Vision

- To develop and market a system which utilizes new and emerging technologies combined with a dynamic software to provide flight guidance to arriving aircraft which will reduce costs associated with arrival flow variance.

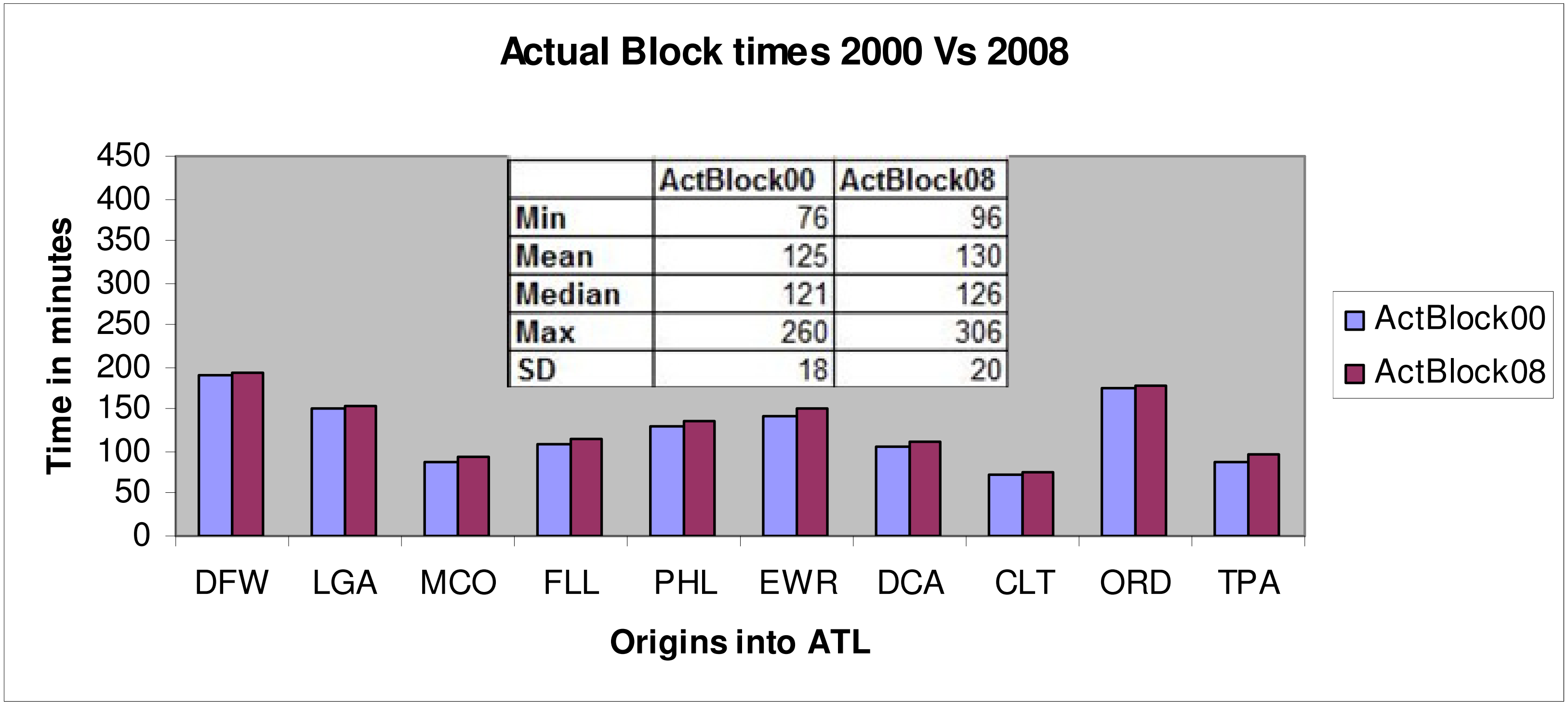
Flight leg phases

Departure/Take-off	Terminal	En-route	Terminal	Landing



The **Initial Approach Fix/Corner post** is the point where the initial approach segment of an instrument approach begins. It is the start of the terminal area for inbound flights.

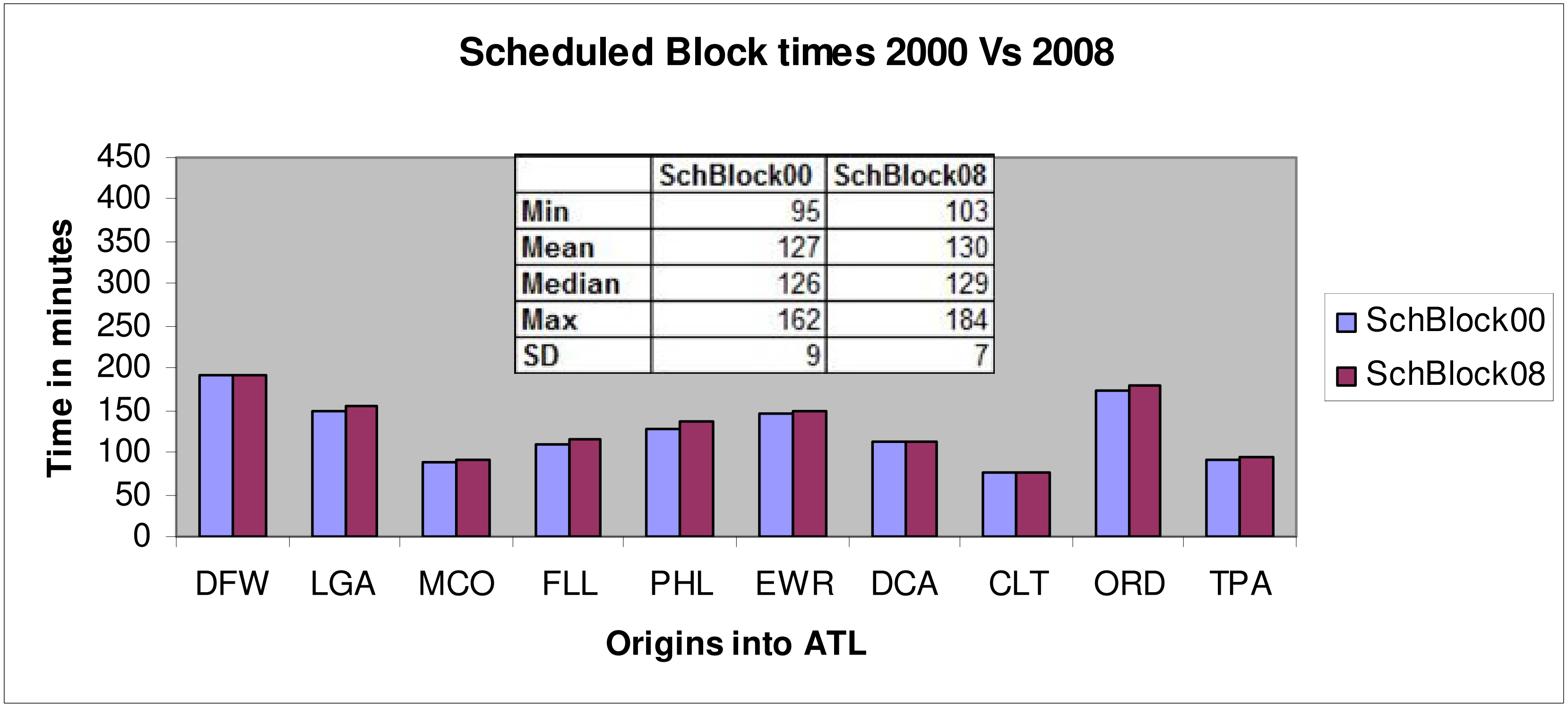
Ever Increasing Block Times



• Block Time – Difference between time the flight leaves the gate at the origin to the time it reaches the gate at the destination.

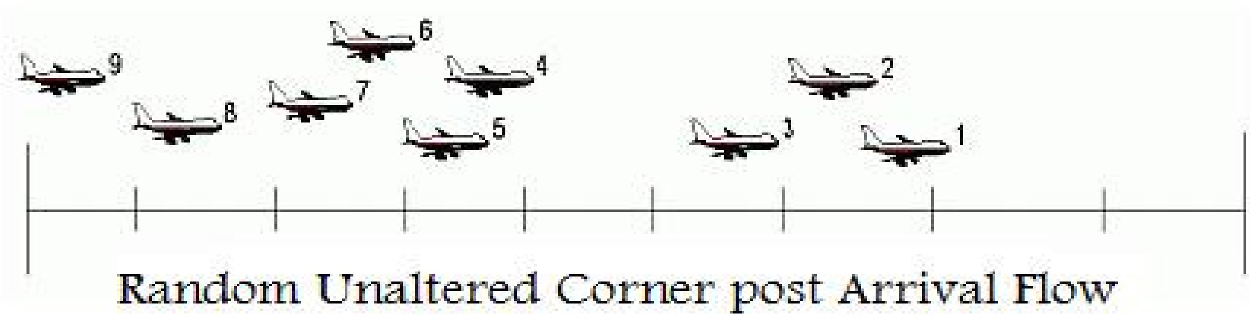
•On an average the Actual block times for flights into ATL went up nearly 4% in 2008 when compared to 2000

Scheduled Block Times



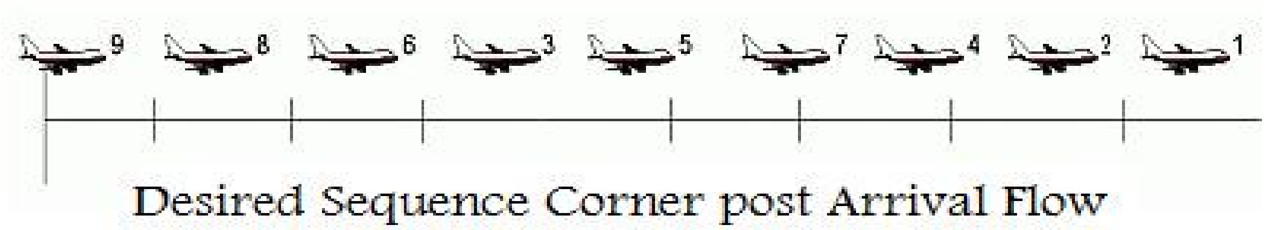
•On an average the Scheduled block times for flights into ATL went up nearly 2.5% in 2008 when compared to 2000

Arrival Flow Variance



- What is Arrival Flow Variance?
  - Random arrivals with undesired inter-arrival times/gaps
- ATC has only one procedure to ensure proper separation between aircraft for landings which is delay/hold flights.
- Symptoms of Arrival Flow Variance
  - Ever increasing block time (more fuel burned)
  - Under-utilization of assets
  - Less satisfied customers and system throughput
  - Increased production of green house gasses (CO_2/NOX emissions)

Properly Sequence Arrival Flow



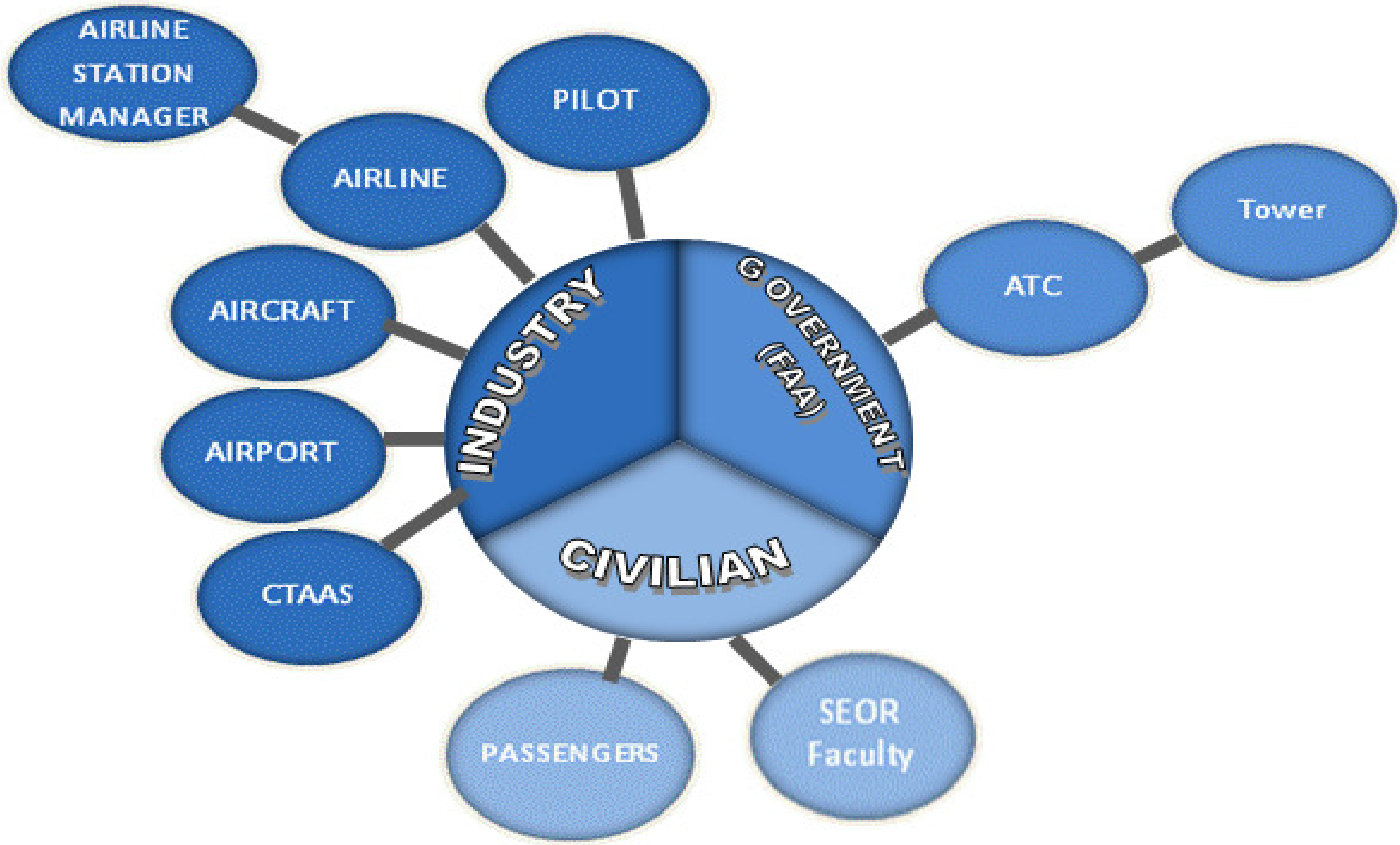
- When aircraft arrive at the corner post with the proper inter-arrival times/gaps they should be able to proceed directly to the runways for landing with minimum delays.
  - However no mechanism is in place to facilitate synchronized sequenced arrivals.

Problem Statement

- Problem: Arrival Flow Variance causes Unbalanced Utilization of Airline/Airport Resources.
  - Random Unbalanced Corner Post Arrivals
  - More than required Aircraft Separation
    - Reduced Runway Throughput
    - Excess Airborne Delay (Holding Pattern)
    - Excess Fuel burn / Emission

Stakeholder Identification

CTAAS Stakeholder Community

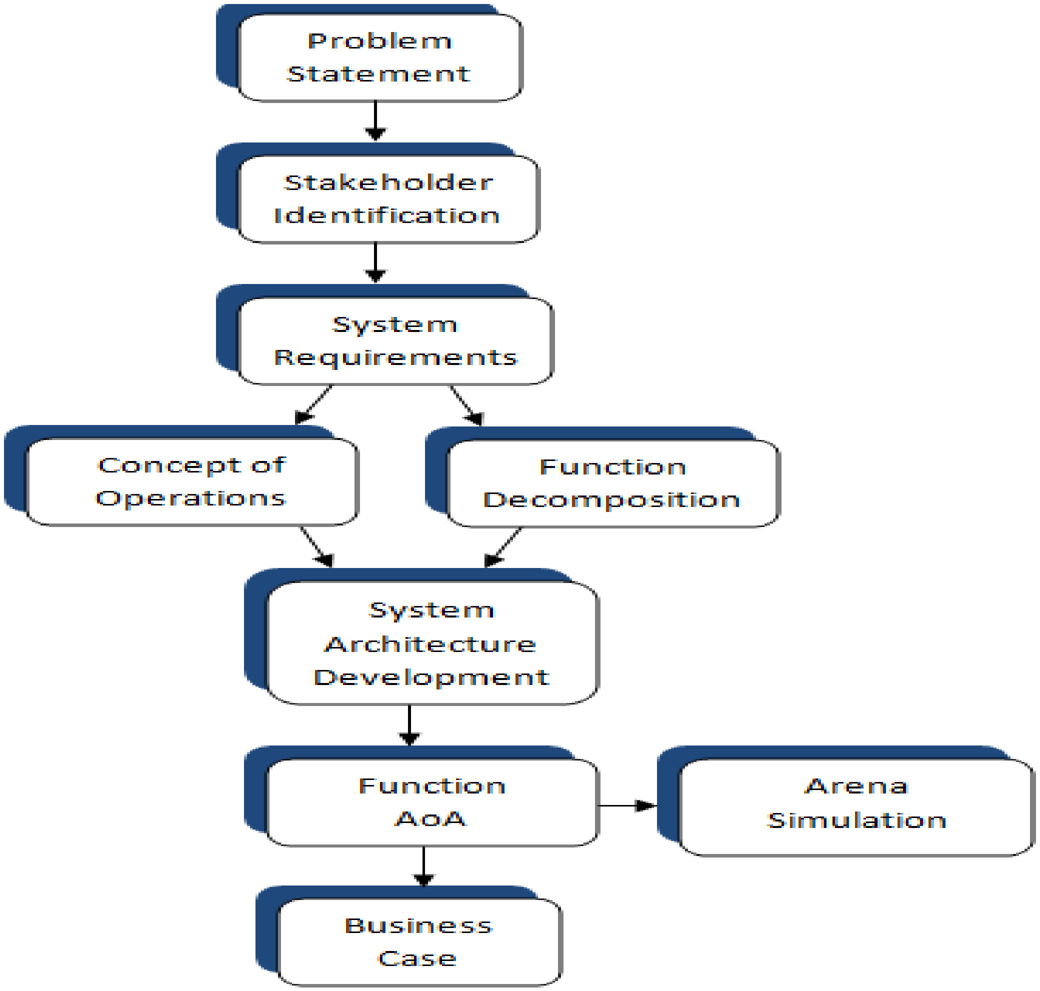


Value Mapping

Stakeholder Matrix										
Need #	Needs/Wants	Stakeholder							Relative Percentage Weight
		Airline – ASM (5)	FAA-ATC- Tower (5)	Airport (4)	Pilots (3)	Passengers (2)	Aircraft Producers (1)	SEOR Faculty (1)	
1	Minimize cost	4	1	4	1	4	4	3	59
2	Increasing Safety	4	4	4	4	4	4	4	84
3	Optimal utilization of Resources	4	4	4	3	1	4	4	75
4	Eased Workload	3	4	3	4	1	3	2	66
5	Convenience	2	2	2	4	4	1	2	51
6	Increased Sales/Revenue	4	0	4	1	0	4	0	43
7	Improve Operations	4	4	4	3	0	3	4	72

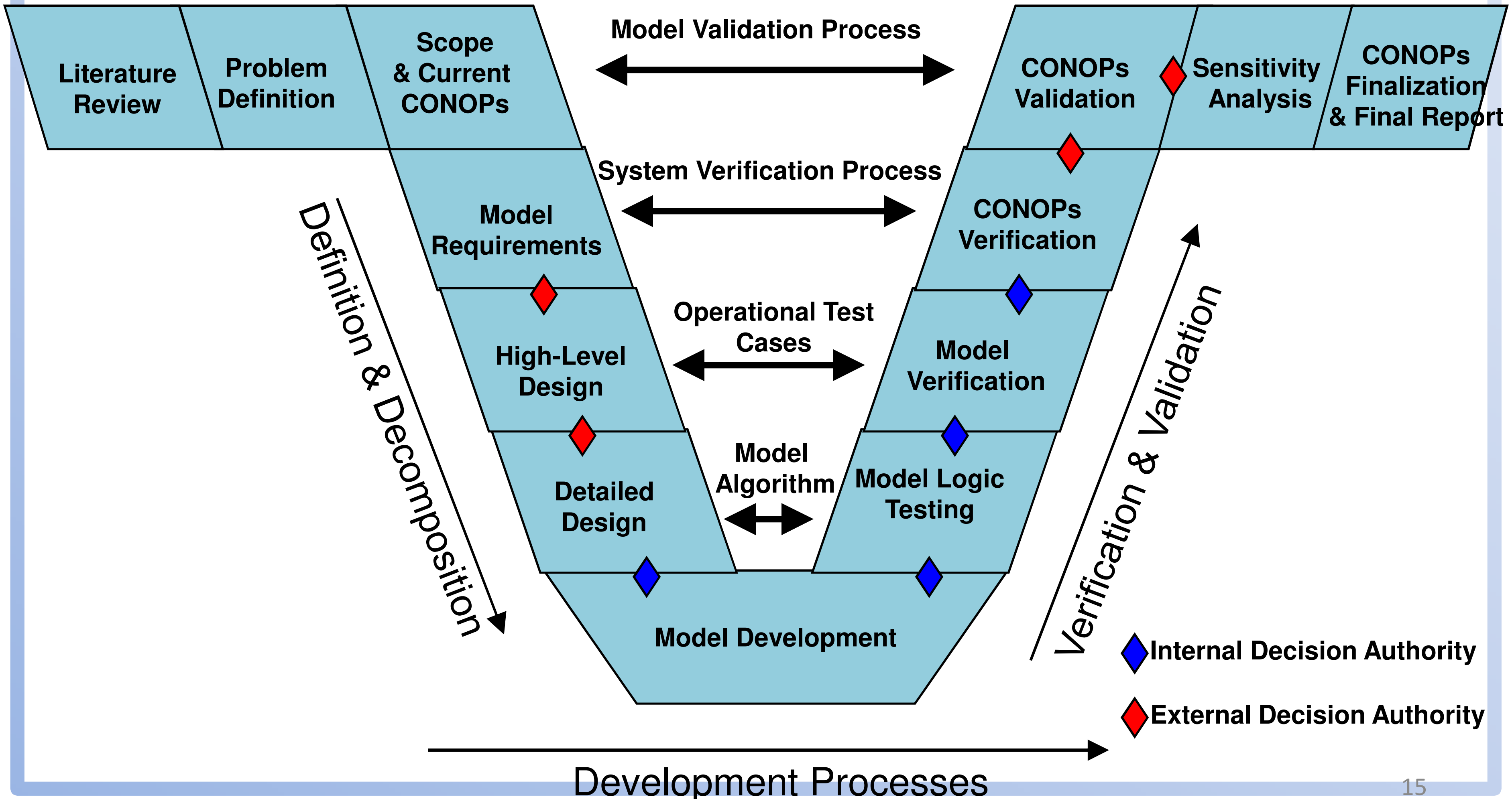
Stakeholder Needs Matrix

Deliverable Value Map



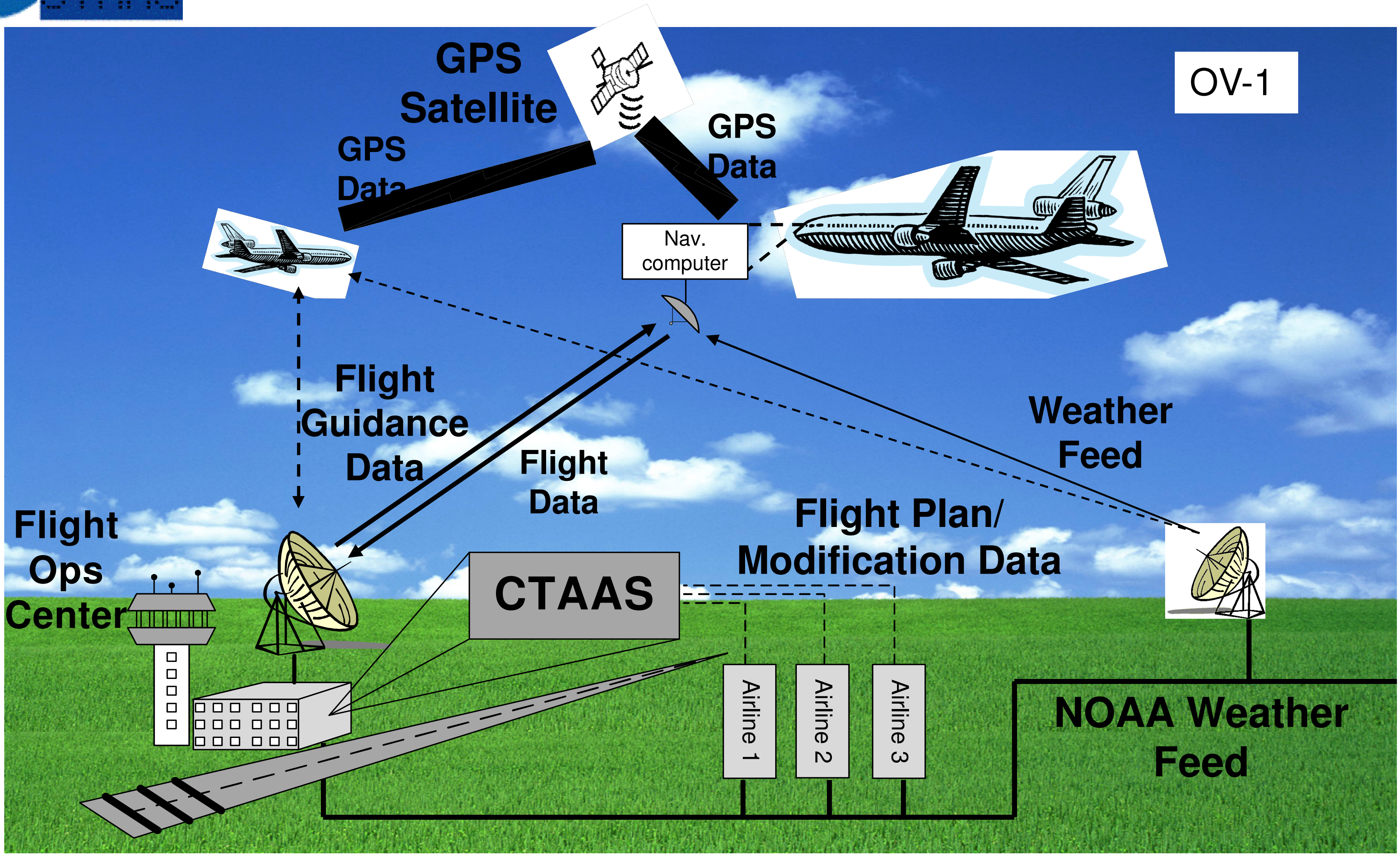
CTAAS Project Development Process

Based on ITS (Intelligent Transportation Systems) framework.

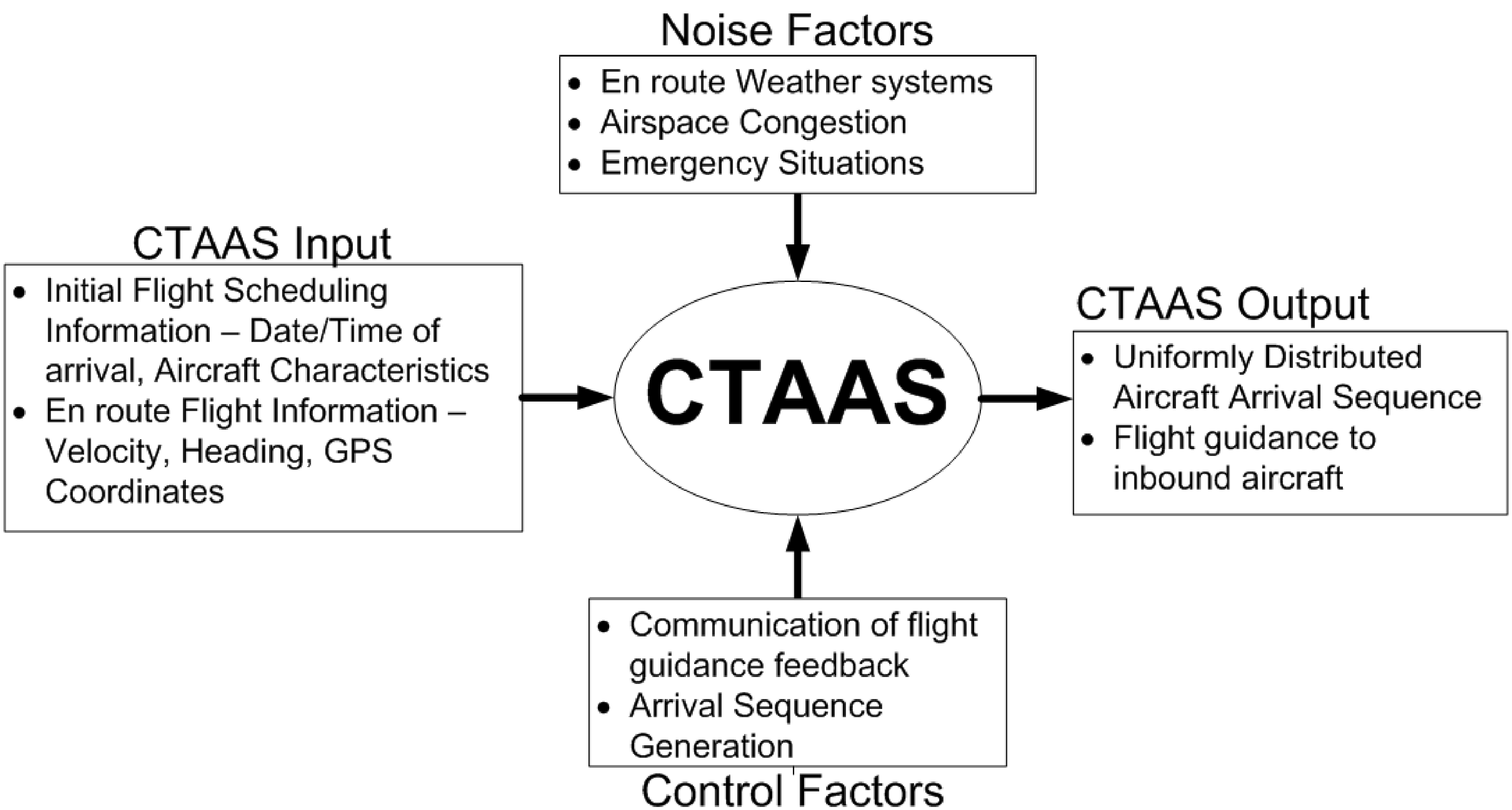


CTAAS CONOPS

CTAAS Concept of Operations



CTAAS Parameter Diagram

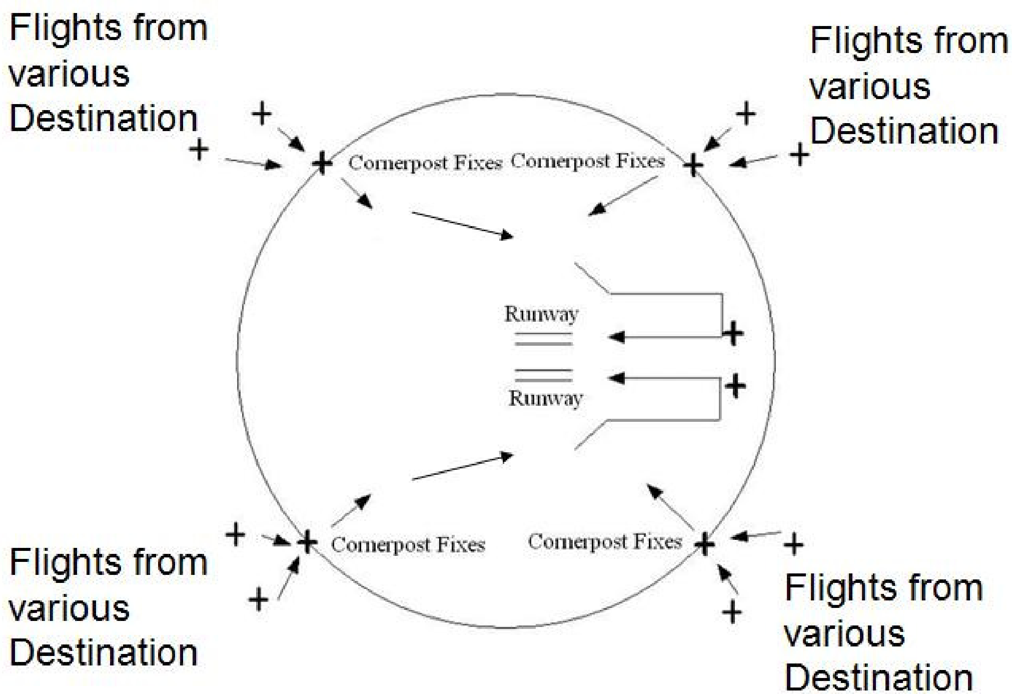


CTAAS Functions & Form Selection

- CTAAS Requirements Analysis
  - Five High-level Functions
  - 17 “Tier-2” functions
- Analysis of the “ilities” requirements drove form factor recommendations
  - CTAAS Server – High-availability, redundant blade server system
  - CTAAS Network - High-speed, secure connection
  - CTAAS DataComm Link
    - Future Air Navigation System (FANS 2/B)
    - Aeronautical Telecommunications Network (ATN)
  - Global Positioning System
  - Electrical system backup

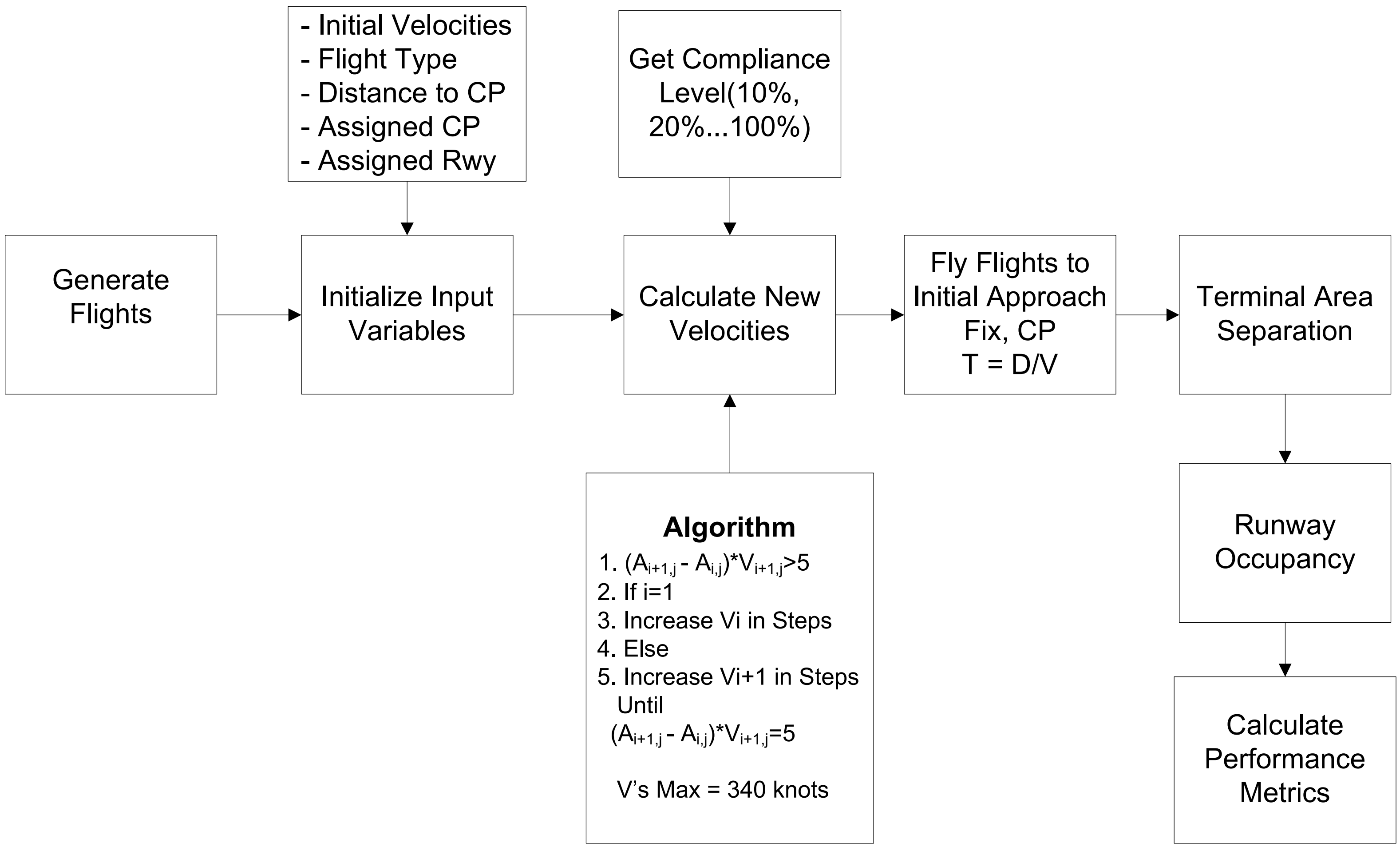
Model Description

Modeling Assumptions

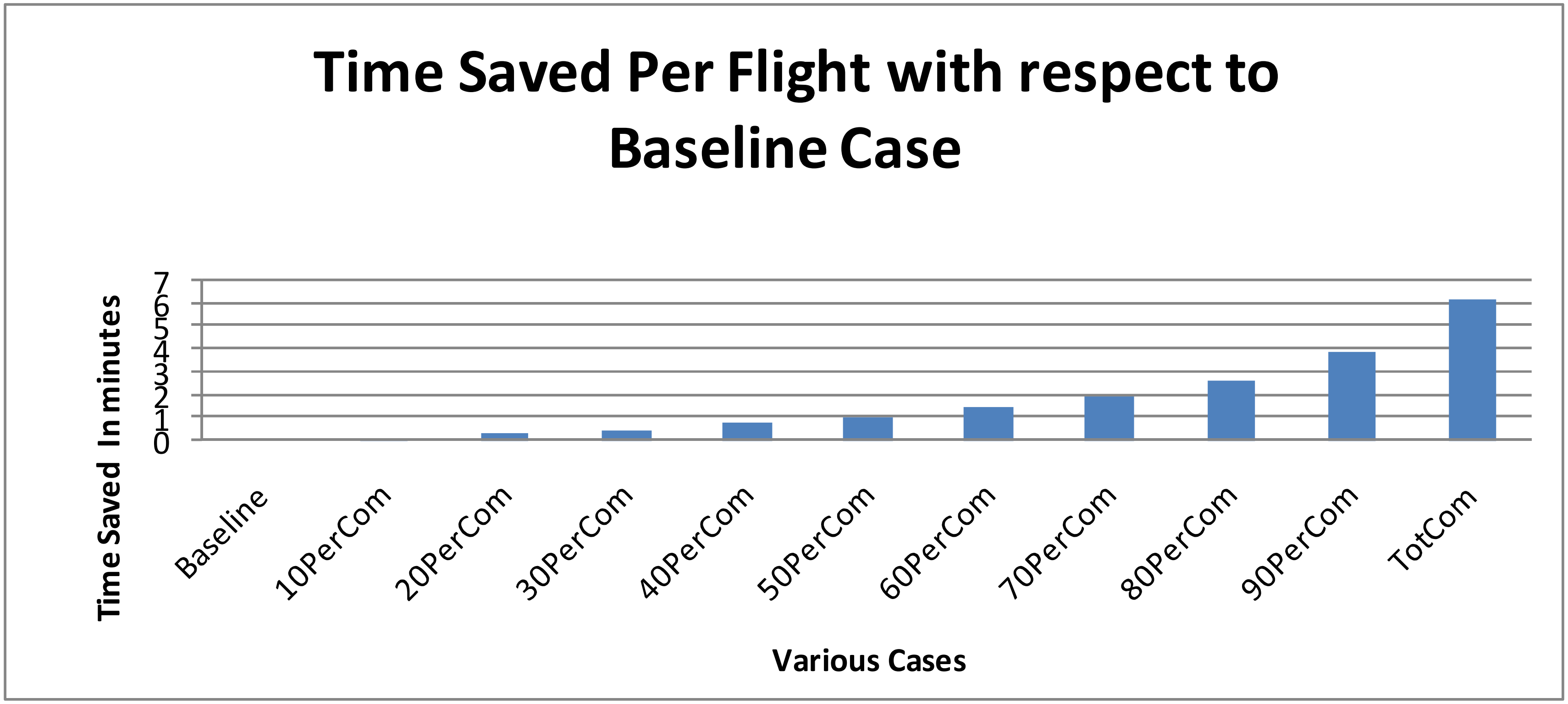


- Velocities assigned to the aircraft are average cruise velocity.
  - For a given case it remains constant
  - Is a function of the separation at the initial approach fix.
- Four Initial approach fix are considered
- The Airport is assumed to have two independent runways.
- Influence of Departures not considered.

Simulation Model Description

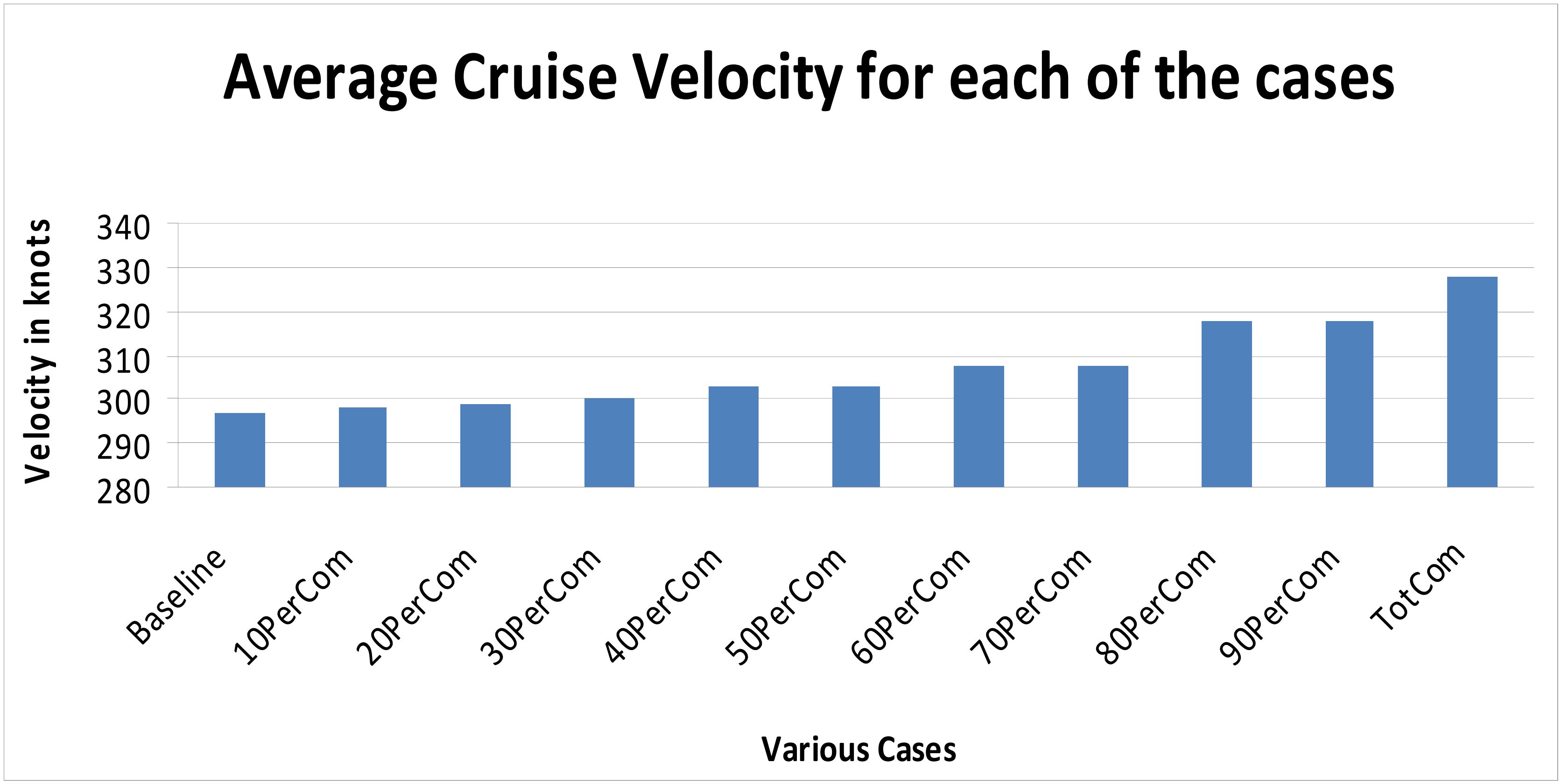


Results – Time Saved with respect to Baseline Case



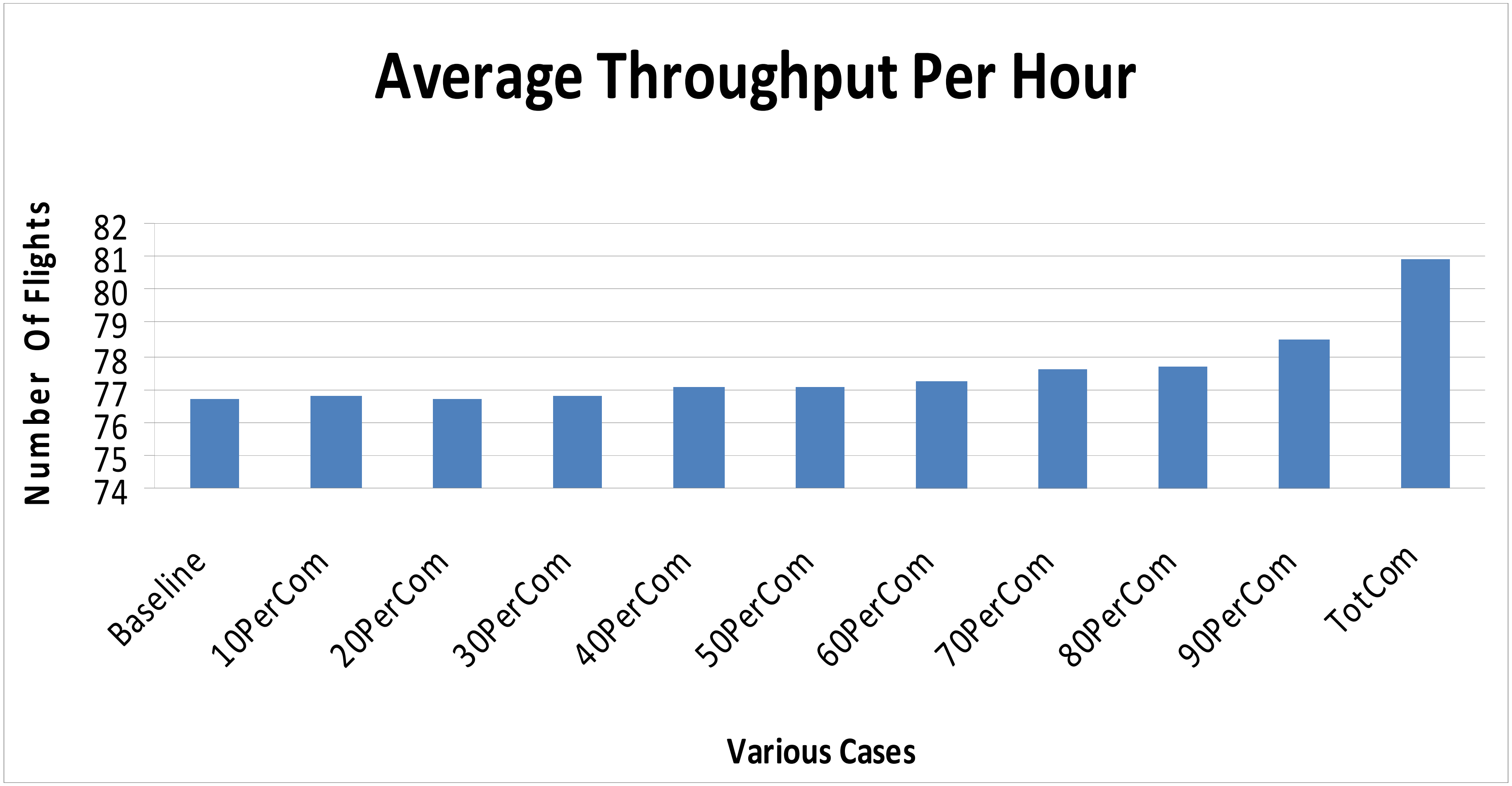
- As much as 6 minutes per aircraft saved

Results – Average Cruise Velocity



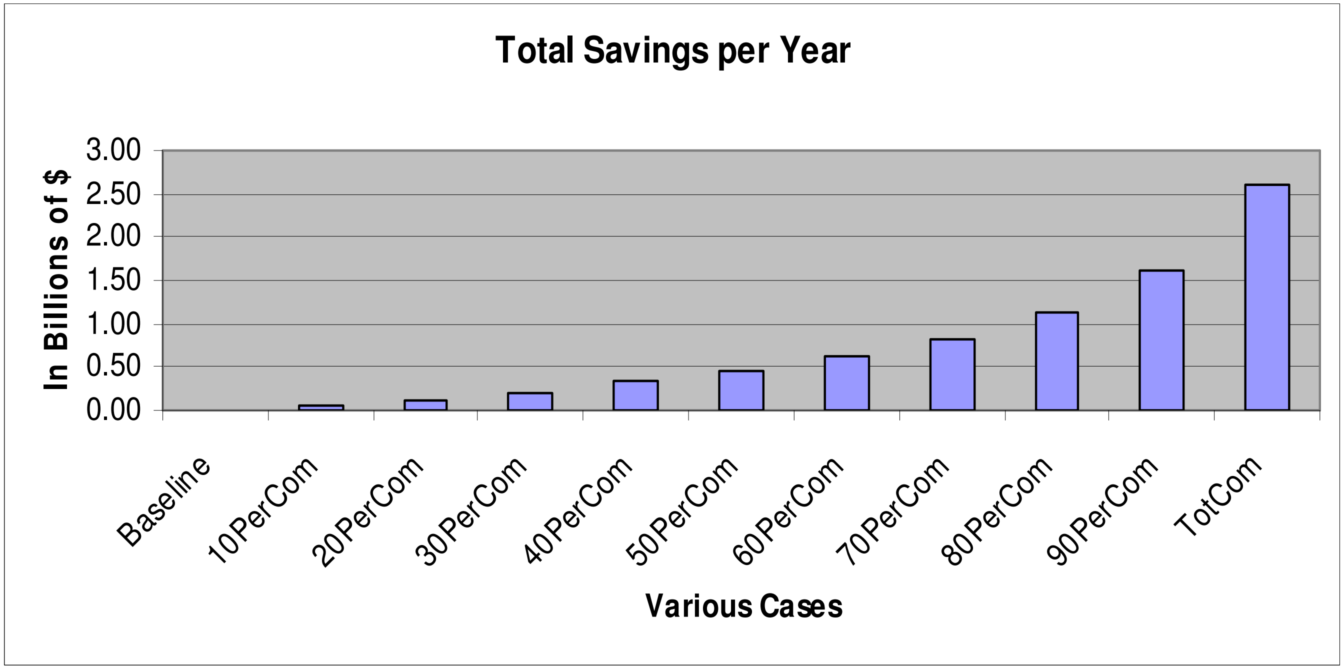
- Average cruise velocity went up by as much as 30 knots

Results – Airport Throughput



- Throughput went up by 5 flights per hour
- Model Airport used 2 Runways

Results – Savings in $ as a result of Block Time Saved



- Savings in Block time = 6 minutes/flight
- Average Number of peak hour Arrivals = 500/airport/day
- Total Block Time saved at OEP-35 Airports = 39.5 million minutes/ Year
- Cost per block minutes = $65.8
- Total saving for airlines per year = $2.6 billion/Year

Business Case

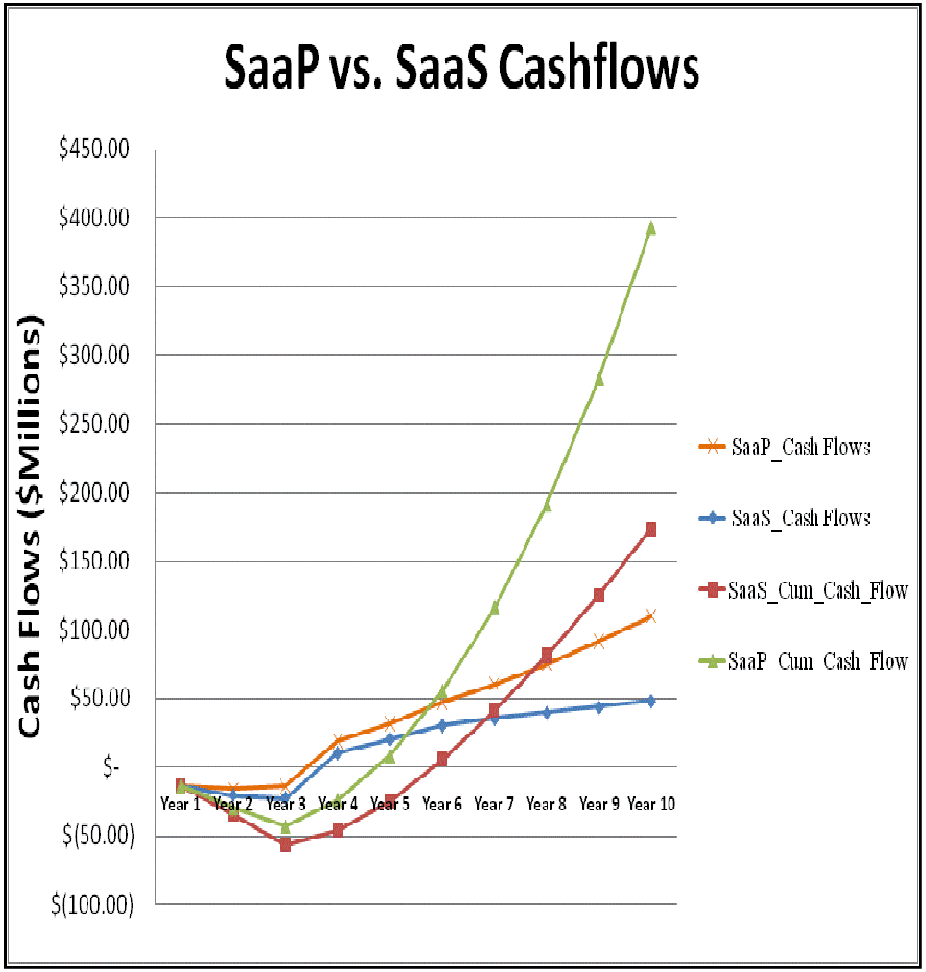
Business Case CONOPs

- There are two concepts of operations:
  - The first concept is simply a software development approach where the CTAAS software will be developed and sold to the customer which in this case would be the FAA (SaaP – software as a product)
  - The second concept of operations is to market CTAAS as a service to the FAA and provide the controlled time of arrival services to those airport that develop delays as a result of variance in aircraft arrivals (SaaS – software as a service)

Financial Assumptions

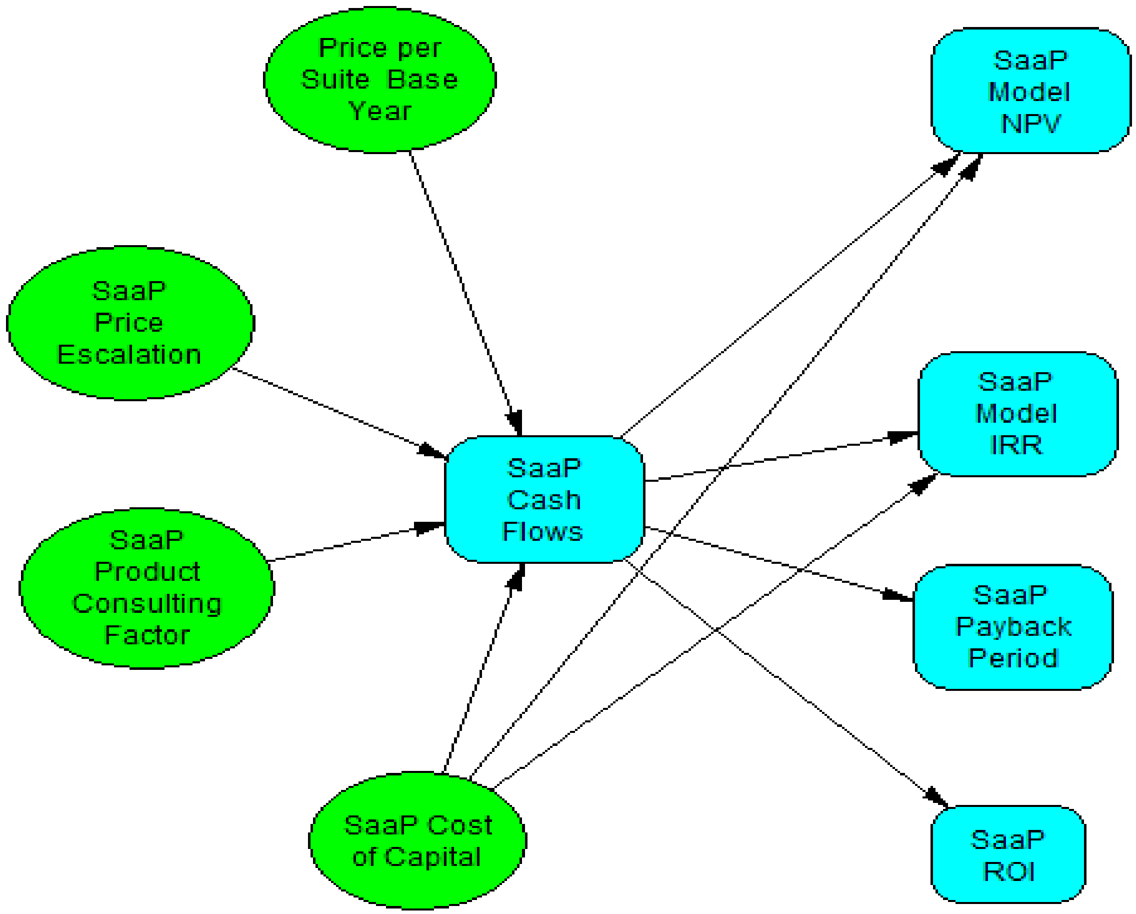
- Cost of Capital: 10%
- Price Escalation Rate: 7.5%
- Period of Evaluation: 10-years
- System Price: $600,000
- Fringe & Fee Rate: 45%
- Consulting Services Factor: 40%

Cashflow Comparison



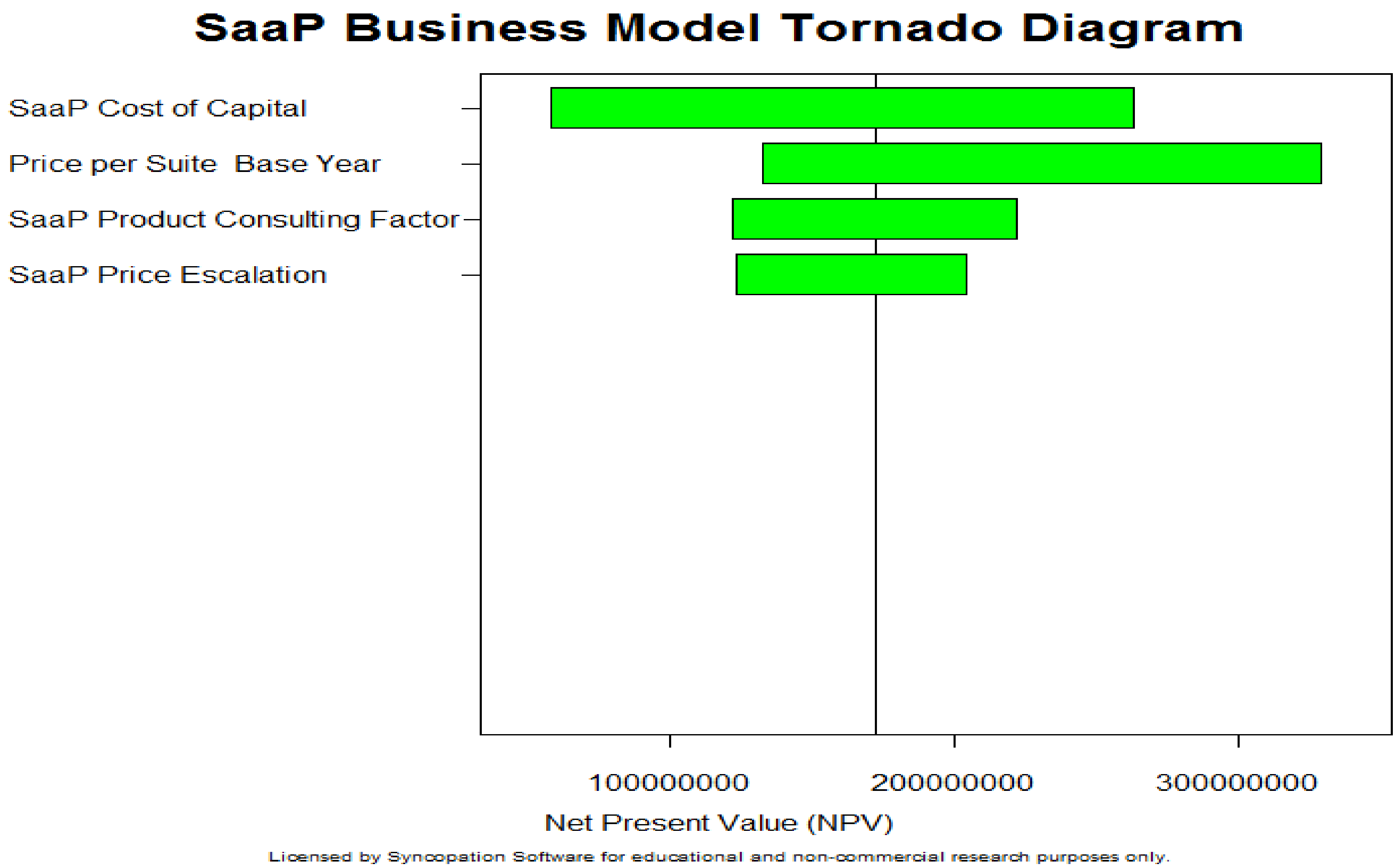
	SaaP	SaaS
Model NPV	$171,921,242.51	$65,727,847.35
Model IRR	54.47%	31.00%
Payback Period	4.73	5.82
ROI	877.02%	294.2%
Required Investment	$ 44,875,687.50	$ 59,046,750.00

Influence Diagrams



SaaP Discrete Stochastic Influence Diagram

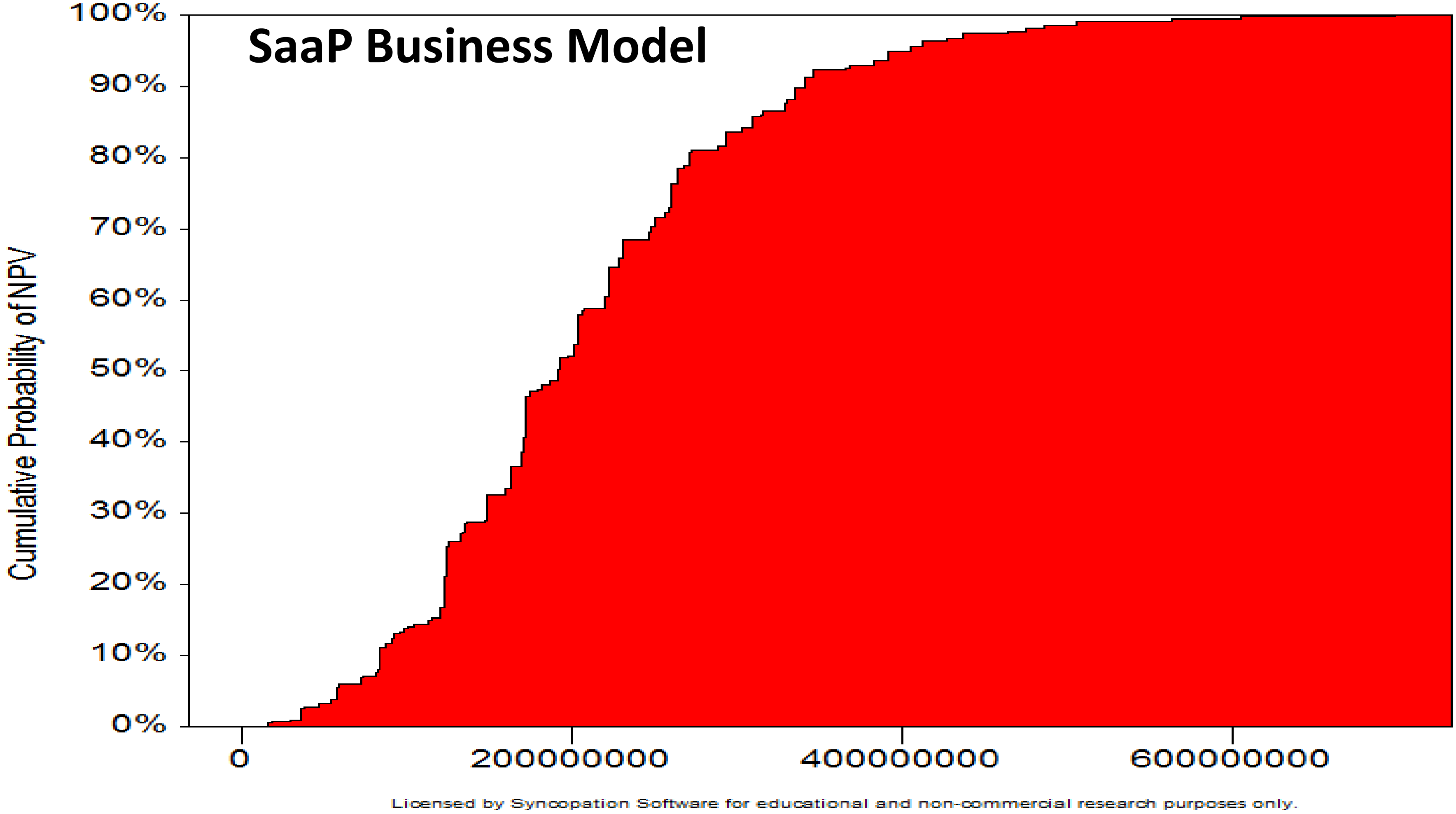
Tornado Diagrams



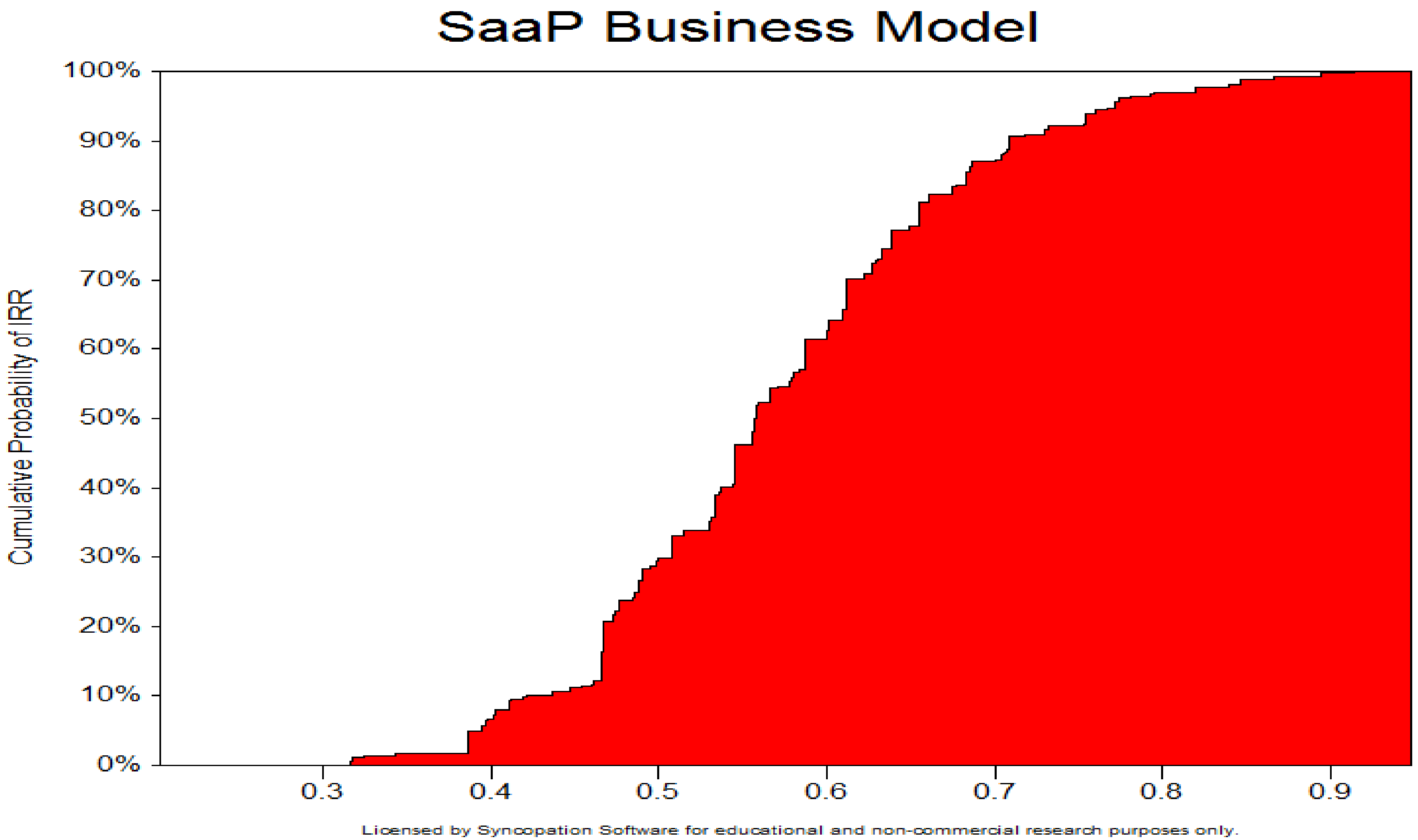
Decision Tree Parameters

	Cost of Capital			Price Escalation			System Price			Consulting Factor		
	Scenario	Value	Probability	Scenario	Value	Probability	Scenario	Value	Probability	Scenario	Value	Probability
SaaP	Low	5.0%	25.0%	Low	1.03	30.0%	Monopoly	$ 1,000,000.00	10.0%	Low	0.25	30.0%
SaaP	Nominal	10.0%	65.0%	Nominal	1.075	40.0%	Aggressive	$ 750,000.00	25.0%	Nominal	0.35	40.0%
SaaP	High	30.0%	10.0%	High	1.1	30.0%	Fair	$ 600,000.00	55.0%	High	0.55	30.0%
SaaP							Competitive	$ 500,000.00	10.0%			

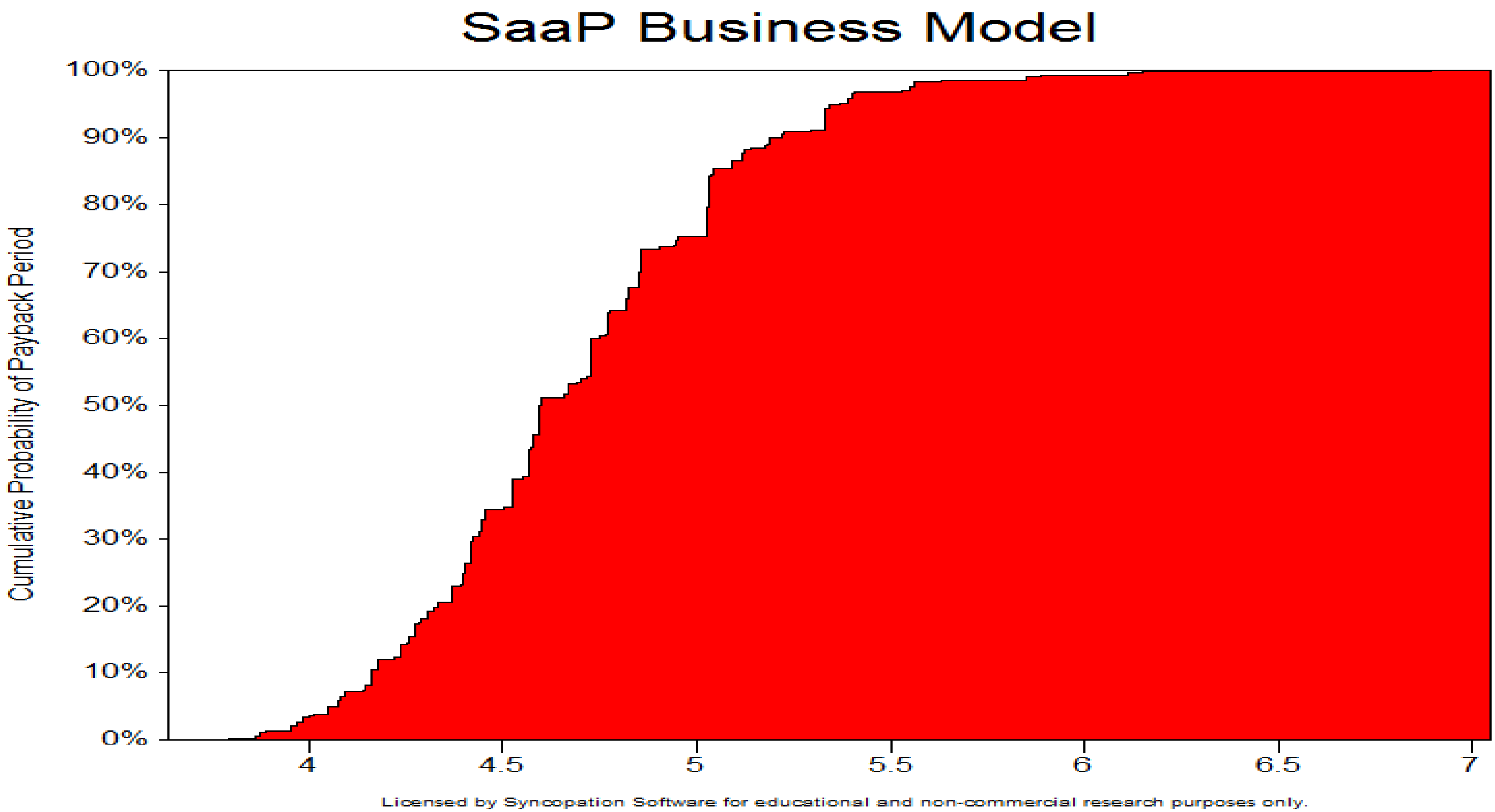
NPV Profile Comparison



IRR Profile Comparison



Payback Period Comparison



Effective Payback Period is approximately 3 years in both models because revenue is not anticipated until Year 3.

Selection Criteria & Results

	SaaS	SaaP
Probability of NPV < 0	1.70%	0.00%
85% of exceeding NPV value	$19.6M	$114.9M
85% of exceeding IRR value	21.10%	46.50%
Probability of Payback Period < 5 years	0.00%	75.00%

Conclusions

- The CTAAS value proposition is ~$2.6B in annual savings to the airlines.
- The 10 year Return on Investment of $44.8M for SaaP is 877%.
- The 10 year Return on Investment of $59M for SaaS is 294%.
- Developing CTAAS as a product would be a profitable business venture.

Future Work

- Obtain Investment for Initial Development and Marketing
- Work with FAA to develop Strategic Communication Plan for the Industry
- Identify Pilot Airports for Initial Deployment
- Continue Improving Sequencing Optimization Algorithms

Thank You

Dr. Speller

Dr. Sherry

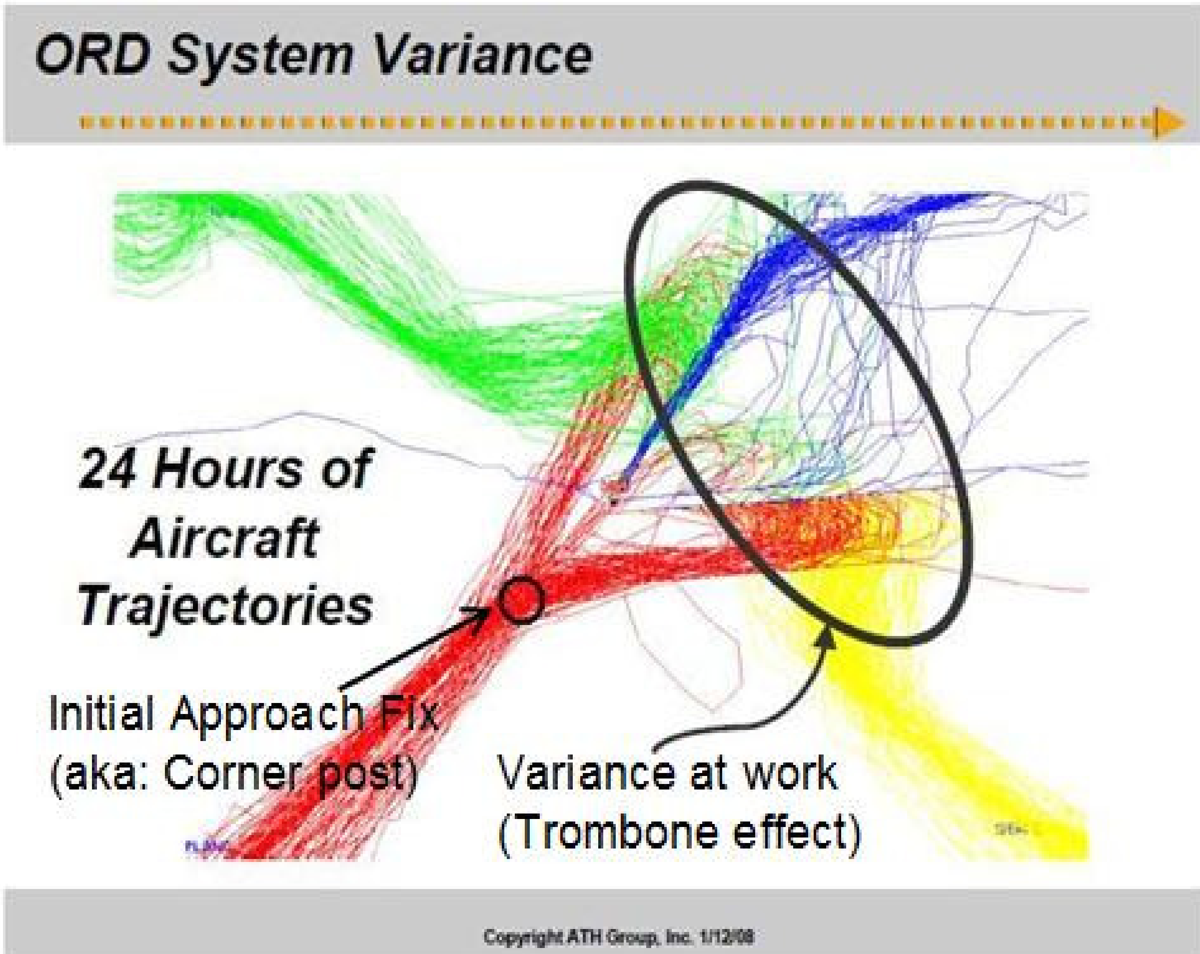
GMU SEOR Faculty

OR680/SE 798 Teams

Questions?

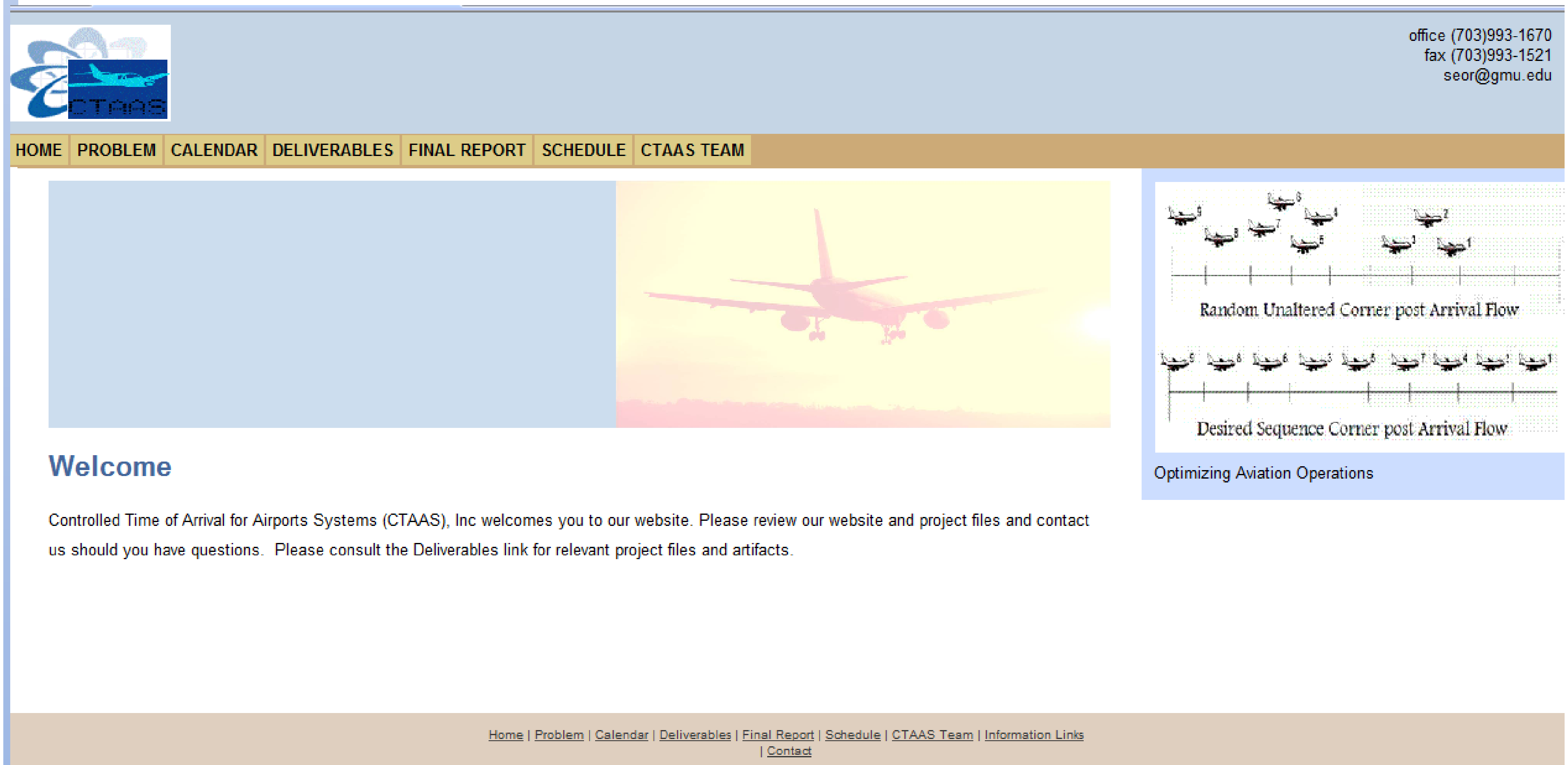
BACK UP SLIDES

Arrival Flow Variance



Source: http://www.athgrp.com/Network_Airline_Problem.pdf

Website Walkthrough

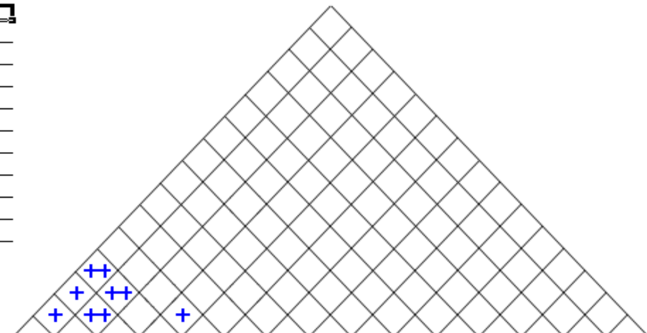


[CTASS Website]

QFD Matrix

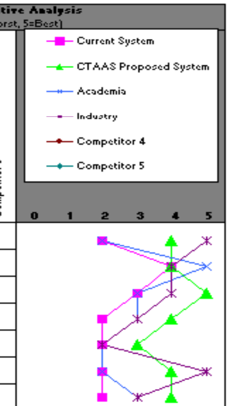
Title:
Author:
Date:
Notes:

Legend		
Θ	Strong Relationship	9
O	Moderate Relationship	3
▲	Weak Relationship	1
++	Strong Positive Correlation	
+	Positive Correlation	
—	Negative Correlation	
▼	Strong Negative Correlation	
▼	Objective Is To Minimize	
▲	Objective Is To Maximize	
x	Objective Is To Hit Target	



Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	Column # → / Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x) / Quality Characteristics (a.k.a. "Functional Requirements" or "Hows") / Demanded Quality (a.k.a. "Customer Requirements" or "Whats")	1 ▲ Accept Aircraft/airlines Request & Acknoledge	2 ▲ Provide Aircraft Flight Guidance	3 ▲ Generate Aircraft Arrival Sequence	4 ▲ Provide Emergency Support	5 ▲ Enable System Maintenance & Servicing	6	7	8	9	10	11	12	13	14	15	Current System	CTAAS Proposed System	Academia	Industry	Competitor 4	Competitor 5
1	9	11.5	3.0	Minimize cost		Θ	Θ		Θ											2	4	2	5		
2	9	19.2	5.0	Increasing Safety		Θ	Θ	Θ	O											4	4	5	4		
3	9	15.4	4.0	Optimal utilization of Resources	O	Θ	Θ	▲	O											3	5	3	4		
4	9	15.4	4.0	Eased Workload	Θ	Θ	Θ	O	▲											2	4	3	3		
5	9	11.5	3.0	Convenience	Θ	▲	▲													2	3	2	2		
6	9	11.5	3.0	Increased Sales/Revenue					Θ											2	4	2	5		
7	9	15.4	4.0	Improve Operations	Θ	O	Θ	Θ	Θ											2	4	3	3		
8																									
9																									
10																									
				Target or Limit Value																					
				Difficulty (0=Easy to Accomplish, 10=Extremely	0	6	7	5	7																
				Max Relationship Value in Column	9	9	9	9	9																
				Weight / Importance	426.9	611.5	703.8	373.1	465.4																
				Relative Weight	16.5	23.7	27.3	14.5	18.0																

Competitive Analysis (0=Worst, 5=Best)



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Project Team Roles

- Project Management: has accountability and responsibility for the project's success, and has the power to make all decisions, subject to oversight by the executive bodies
  - Akshay Belle
- System Architecture Team: develops and manages the development of the system architecture, including functional specification
  - Michael Brinker
- Analytical Team: controlling and tracking the detailed plan, will write and managing documentation, preparing reports and, control and distribute project files, and submit deliverables , including website development and management
  - Najia Hussaini & LaTrent Burdette
- Model Team: responsible for carrying out technical activities within the context of the application, and data, also develops strategic, logical, and physical designs and oversee analysis and implementation activities
  - Akshay Belle & Michael Brinker
- Business Case Team: responsible for the market research, financial model development, and the business case selection criteria
  - Arlen Lippert & LaTrent Burdette
- Quality Assurance Team: responsible for processes and procedures that ensure required levels of quality are achieved
  - Najia Hussani, Arlen Lippert, & Akshay Belle

Stakeholder Identification

- **Air Traffic Control (ATC) – Tower**
  - Increase/maintain safety and runway utilization
- **Pilots**
  - Ease workload and improve perceived safety
- **Airline (Airline Station Manager)**
  - Provide gates and services to all incoming aircrafts
- **Aircraft Producers**
  - Potential for increased business – new and retrofit integration
- **Airport**
  - Effective utilization of Airport Resources
- **CTAAS**
  - Improve Knowledge Base and Learning Curve
- **Passengers**
  - Safety and Convenience
- **SEOR Faculty**
  - Continued contribution to automated air traffic control

Stakeholder Needs/Wants Analysis

STAKEHOLDER GROUPS	NEEDS	WANTS
GOVERNMENT (Air Traffic Control)	•Safety •Decrease Workload •Less Separation Violation	•Less Delays •Effective Technology To Better Utilize Runways
CIVILIAN (Passengers, SEOR Faculty)	•Safety •Reliability	•Cheaper Airfare
INDUSTRY (Pilot, Airliners, Aircraft, Airport, CTAAS)	•Safety •Better System Performance •Better Runway Capacity •Less Fuel Usage •Less Separation Violation •Synchronized Arrival Stream •Decrease Workload	•New Technology •Address Airport Capacity •Customize Model Airports •Customize Airspace •Meet ATC Requirements •Qualitative Inter-Arrival Times •Decrease Cost •Increase Revenue •Less Delays

Value Mapping

Assessment Scale	
4	Critical to stakeholder satisfaction
3	Highly recommended for stakeholder satisfaction
2	Some value but not to the full stakeholder's satisfaction
1	Minimum value but not necessary to stakeholder satisfaction
0	No value to stakeholder satisfaction

Stakeholder Weights	
5	Airline – Airline Station Manager
5	Air Traffic Control - Tower
4	Airport
3	Pilots
2	Passengers
1	Aircraft Producers
1	SEOR Faculty

Stakeholder Weights

Value Mapping (2)

Stakeholder Matrix									
Need #	Needs/Wants	Stakeholder							Relative Percentage Weight
		Airline – ASM	ATC- Tower	Airport	Pilots	Passengers	Aircraft Producers	SEOR Faculty	
1	Minimize cost	4	1	4	1	4	4	3	59
2	Increasing Safety	4	4	4	4	4	4	4	84
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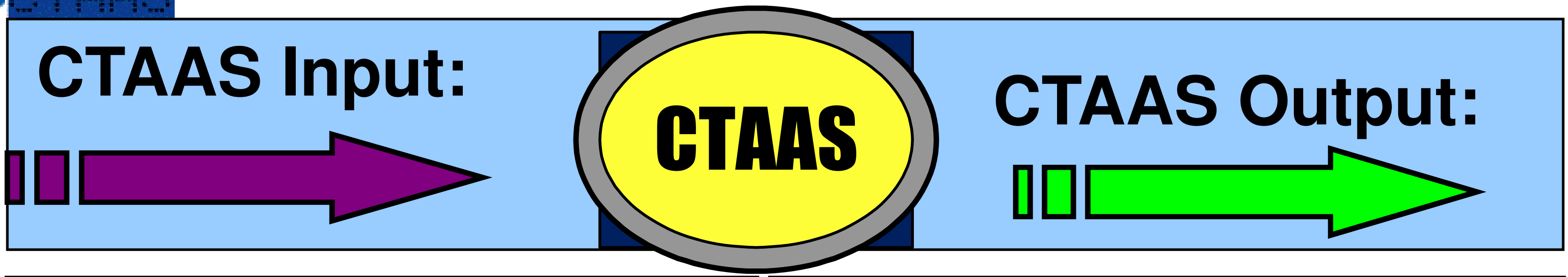
5	Convenience	2	2	2	4	4	1	2	51
6	Increased Sales/Revenue	4	0	4	1	0	4	0	43
7	Improve Operations	4	4	4	3	0	3	4	72

Stakeholder Needs Matrix

CTAAS Input/Output



- CTAAS Input
  - Initial Flight Schedule Information
    - Date/Time of Arrival
    - Aircraft Characteristics
      - Velocity Parameters
  - Inbound Flight Information
    - Current Velocity
    - Heading
    - Physical Coordinates (Lat/Long)

- CTAAS Output
  - Uniformly Distributed Aircraft Arrival Sequence
    - Balanced Distribution of Aircraft Arrival Times
  - Provide En Route Flight Guidance to Inbound Aircraft

- End Result:

  -Improved Runway Utilization

  -Reduced Cost to Airlines

Sub-Functions and Forms

High Level Functions	Sub Functions	System Component Involved
1.- Accept Aircraft/Airlines Request & Acknowledge	1.1 - Support Aircraft Requests	CTAAS System User Interface, Airline AOC Interface, CTAAS Data link
	1.2 - Support Airlines' Requests	CTAAS System User Interface, Airline Scheduling Interface, CTAAS Data link
	1.3 - Support Aircraft/Airline Entities' Requests in Emergency	CTAAS System Interface, Airline AOC Interface, Emergency Support Entity Interface, Emergency Communication Channels, CTAAS Data link
2.- Generate Balanced Aircraft Arrival Sequence	2.1 - Receive & Process Messages	CTAAS System User Interface, Airline Scheduling Interface, Airline AOC Interface, CTAAS Data link
	2.2 - Send Acknowledgement Messages	CTAAS System User Interface, Airline AOC Interface, CTAAS Data link
	2.3 - Enqueue Aircraft & Balance Flow	CTAAS System
	2.4 - Emergency Support	CTAAS System Interface, Airline AOC Interface, Emergency Support Entity Interface, Emergency Communication Channels, CTAAS Data link

Sub-Functions and Forms (Contd.)

High Level Functions	Sub Functions	System Component Involved
3.- Provide Aircraft Flight Guidance	3.1 - Receive Sequence Requirements	CTAAS System User Interface, Airline AOC Interface, CTAAS Data link
	3.2 - Provide Aircraft Flight Control Direction	CTAAS System User Interface, Airline AOC Interface, CTAAS Data link
4.- Provide Emergency Support	4.1 - Receive & Process Emergency Message	CTAAS System User Interface, Airline AOC Interface, CTAAS Data link
	4.2 - Send Ack. of Emergency Message	CTAAS System User Interface, Airline AOC Interface, CTAAS Data link
	4.3 - Send Emergency Action-Related Message & Direction	CTAAS System Interface, Airline AOC Interface, Emergency Support Entity Interface, Emergency Communication Channels, CTAAS Data link
5. - Enable System Maintenance and Servicing	5.1 - Receive Service/Maintenance Request	CTAAS System, Facility Support Interface
	5.2 - System Analysis	CTAAS System
	5.3 - Conduct Maintenance	CTAAS System, Facility Support Interface
	5.4 - Report System Diagnostic & Status Messages	CTAAS System, Facility Support Interface, Airlines AOC Interface

Sub Functions and Forms

High Level Functions	Sub Functions	System Component Involved
1.- Accept Aircraft/Airlines Request & Acknowledge	1.1 - Support Aircraft Requests	CTAAS System User Interface, Airline AOC Interface, CTAAS Datalink
	1.2 - Support Airlines' Requests	CTAAS System User Interface, Airline Scheduling Interface, CTAAS Datalink
	1.3 - Support Aircraft/Airline Entities' Requests in Emergency	CTAAS System Interface, Airline AOC Interface, Emergency Support Entity Interface, Emergency Comms Channels, CTAAS Datalink
2.- Generate Balanced Aircraft Arrival Sequence	2.1 - Receive & Process Messages	CTAAS System User Interface, Airline Scheduling Interface, Airline AOC Interface, CTAAS Datalink
	2.2 - Send Acknowledgement Messages	CTAAS System User Interface, Airline AOC Interface, CTAAS Datalink
	2.3 - Enqueue Aircraft & Balance Flow	CTAAS System
	2.4 - Emergency Support	CTAAS System Interface, Airline AOC Interface, Emergency Support Entity Interface, Emergency Comms Channels, CTAAS Datalink

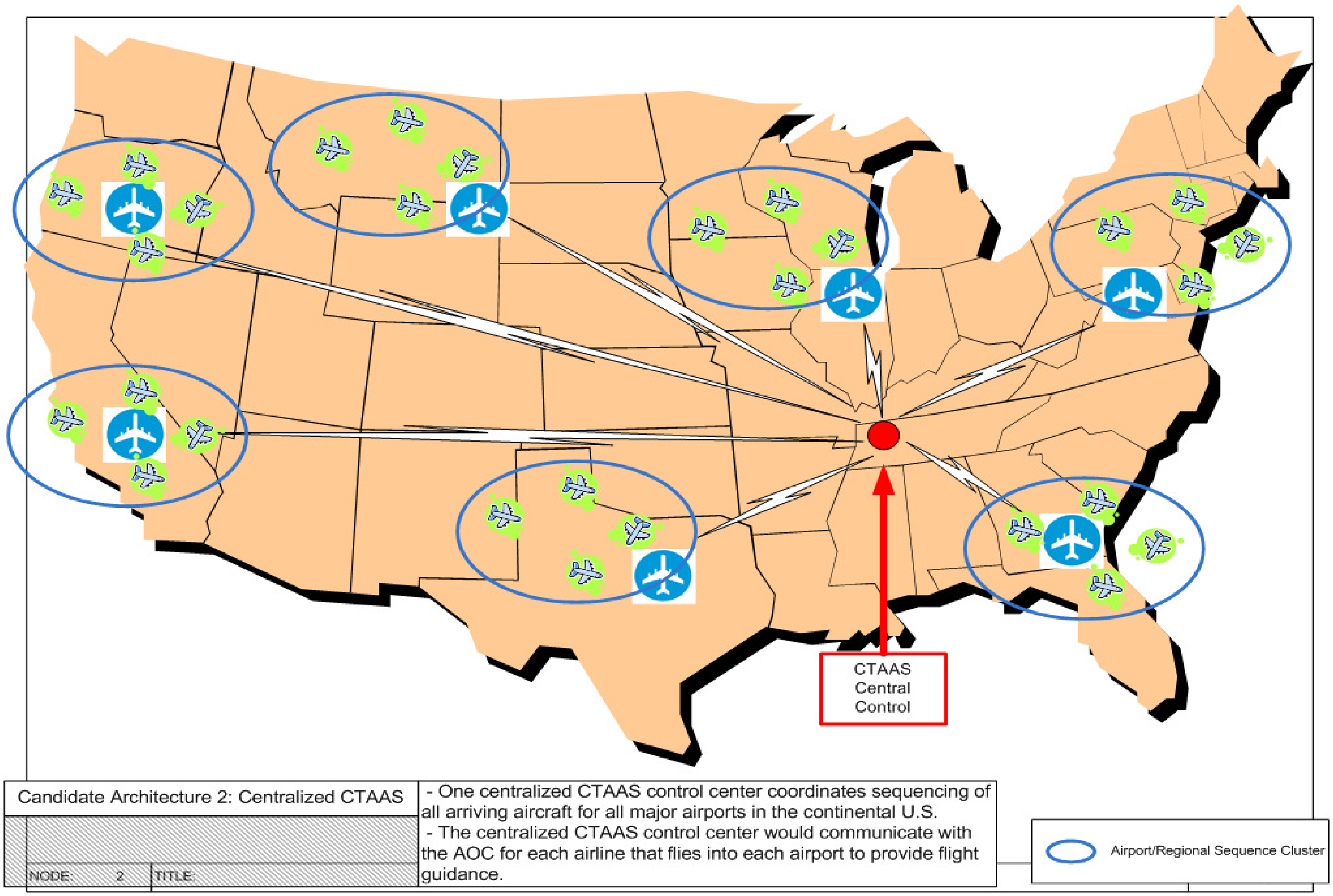
Sub Functions and Forms (Contd.)

High Level Functions	Sub Functions	System Component Involved
3.- Provide Aircraft Flight Guidance	3.1 - Receive Sequence Requirements	CTAAS System User Interface, Airline AOC Interface, CTAAS Datalink
	3.2 - Provide Aircraft Flight Control Direction	CTAAS System User Interface, Airline AOC Interface, CTAAS Datalink
4.- Provide Emergency Support	4.1 - Recieve & Process Emergency Message	CTAAS System User Interface, Airline AOC Interface, CTAAS Datalink
	4.2 - Send Ack. of Emergency Message	CTAAS System User Interface, Airline AOC Interface, CTAAS Datalink
	4.3 - Send Emergency Action-Related Message & Direction	CTAAS System Interface, Airline AOC Interface, Emergency Support Entity Interface, Emergency Comms Channels, CTAAS Datalink
5. - Enable System Maintenance and Servicing	5.1 - Receive Service/Maintenance Request	CTAAS System, Facility Support Interface
	5.2 - System Analysis	CTAAS System
	5.3 - Conduct Maintenance	CTAAS System, Facility Support Interface
	5.4 - Report System Diagnostic & Status Messages	CTAAS System, Facility Support Interface, Airlines AOC Interface

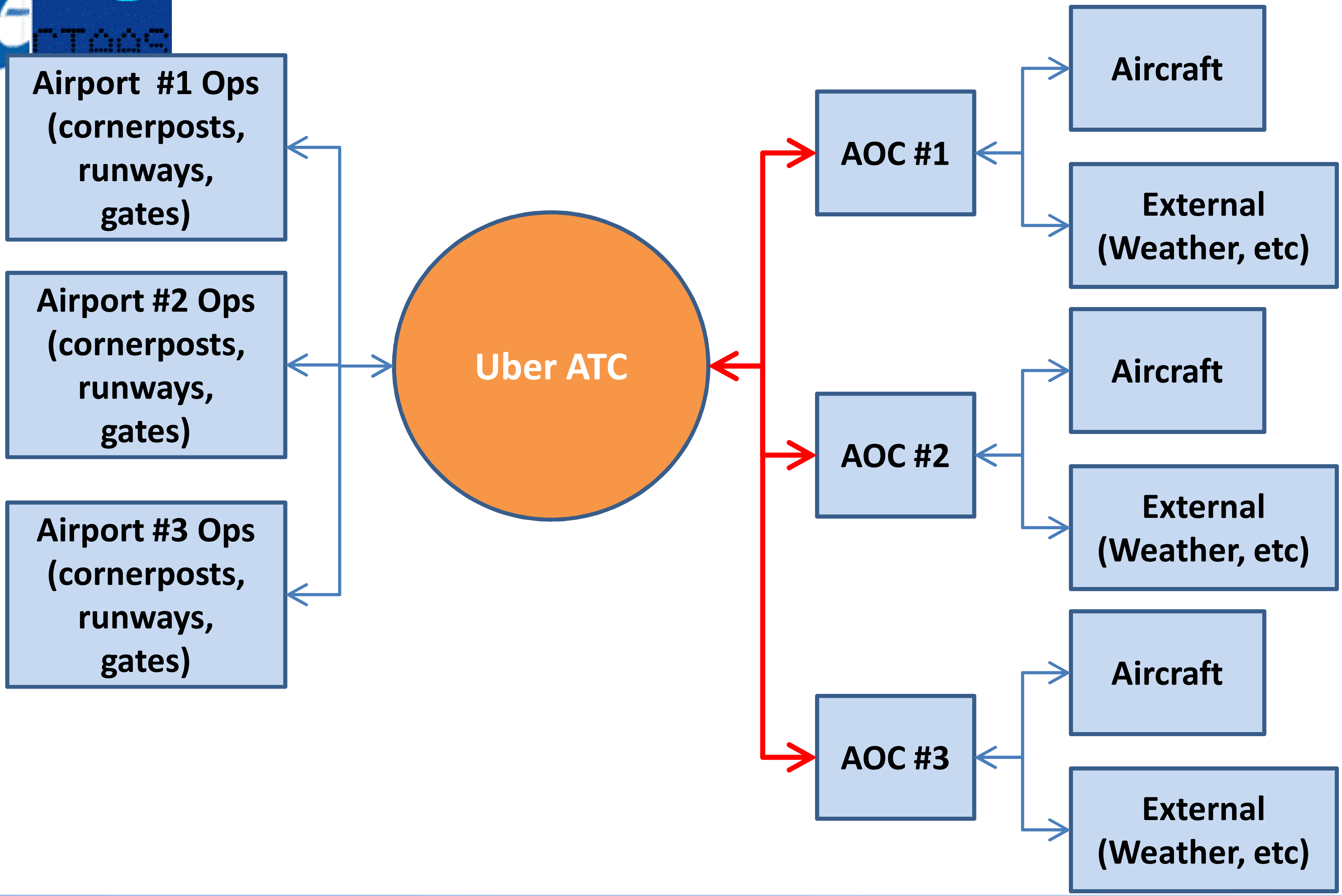
Candidate System Architectures

- Decentralized – Airport Control
- Centralized – Uber AOC
- Distributed Network

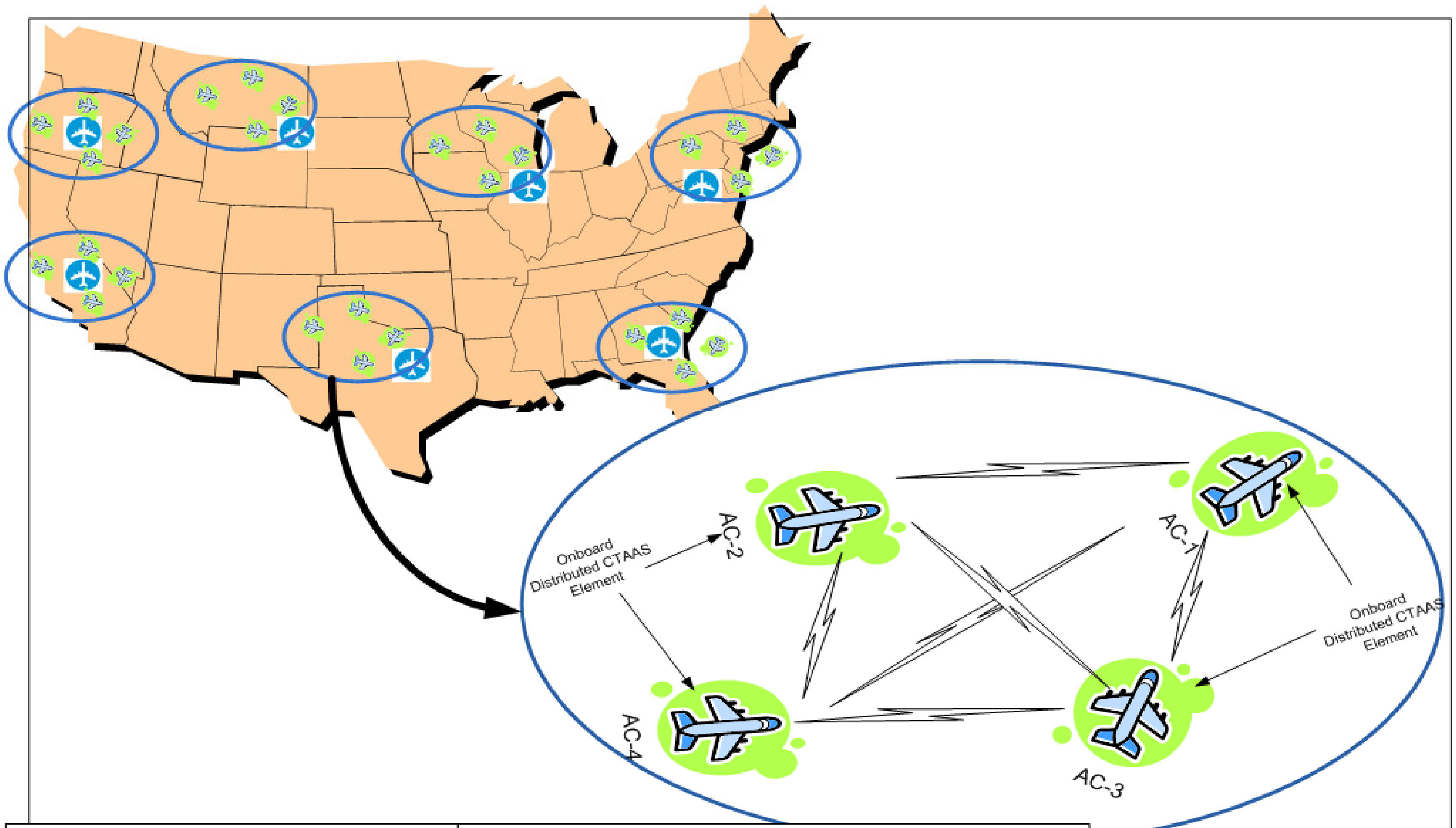
Centralized – Uber ATC



Centralized – Uber ATC



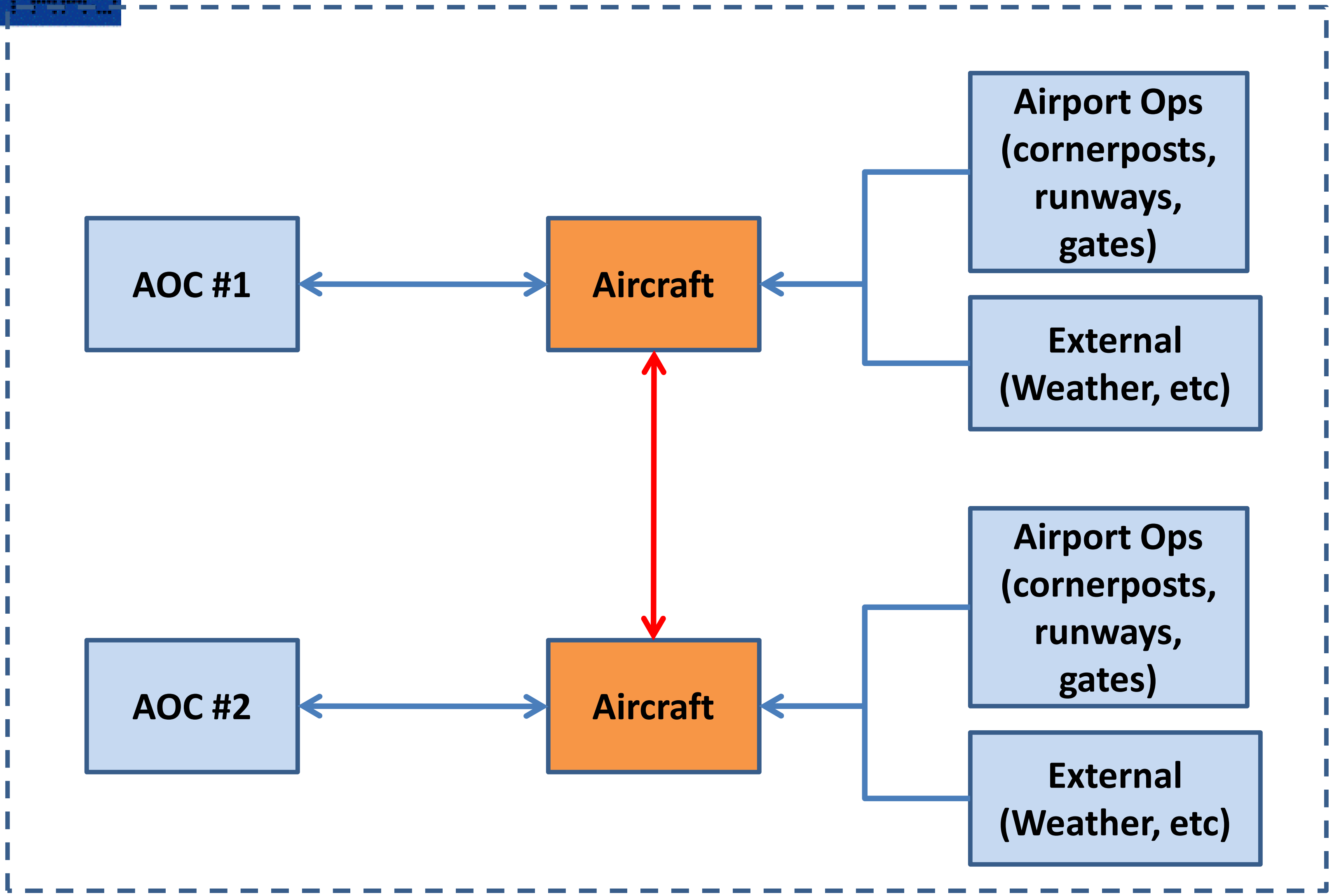
Distributed Network



Candidate Architecture 1: Distributed CTAAS	- All Aircraft enroute to same destination airport are in communication regarding flight characteristics, current location, speed, etc. - Distributed CTAAS system will assign sequencing slots via collaborative decision making, and will self-regulate arriving aircraft to ensure correct arrival sequencing.
NODE: 1 TITLE:	

NO.: pg. 1

Distributed Network – Collaborative Sequencing



Architecture Selection

Architecture	COST	Safety	Optimal Utilizes Existing Resources	Low Workload	Convenience	Rise in Sales	Improves Operations	SCORE
Decentralized	3	4	3	3	5	4	4	**26**
Centralized	4	1	4	2	1	3	2	**17**
Distributed Network	1	4	1	1	4	2	1	**14**
	5: Best	1: Worst						

Based on our analysis, decentralized architecture system works the best.

Function Form Selection

- Function 1:
  - Accept Aircraft/Airlines Request & Acknowledge
- Forms:
  - Radio
  - Data Link
  - Satellite Communication

Function Form Selection

- Function 1: Accept Aircraft/Airlines Request & Acknowledge

FORM	COST	Safety	Optimal Utilizes Existing Resources	Low Workload	Convenience	Increase Sales	Improves Operations	SCORE
Radio	5	4	5	2	2	3	2	23
Date Link	4	3	4	5	5	3	5	29
Satellite-Comm	2	4	2	5	5	3	5	26
	5: Best	1: Worst						

Function Form Selection

- Function 2:
  - Generate Aircraft Arrival Sequence
- Forms
  - Analytical Model
    - Apply Queuing and Network models.
    - Derive equations describing the system.
  - Simulation Model
    - Build Simulation models
    - Design Experiments
      - Do nothing
      - Improve Utilization
      - Improve Compliance
      - Improve Utilization + Compliance
    - Perform Sensitivity Analysis and compare alternatives.
  - Manual control (Human in loop).

Function Form Selection

- Function 2:
  - Generate Aircraft Arrival Sequence

Form	COST	TIME	PERFORMANCE	TOTAL
Manual	1	1	3	5
Simulation	3	4	4	11
Analytical	4	2	2	8
	5:Best	1:Worst		

Function Form Selection

- Function 3:
  - Provide Aircraft Flight Guidance
- Forms:
  - Radio
  - Data Link
  - Satellite Communication

Function Form Selection

- Function3: Provide Aircraft Flight Guidance

FORM	COST	Safety	Optimal Utilizes Existing Resources	Low Workload	Convenience	Increase Sales	Improves Operations	SCORE
Radio	5	4	5	2	2	3	2	23
Data link	4	3	4	5	5	3	5	29
Satellite-Comm	2	4	2	5	5	3	5	26
	5: Best	1: Worst						

Function Form Selection

- Function 4:
  - Provide Emergency Support
- Forms:
  - Radio
  - Data Link
  - Satellite Communication

Function Form Selection

- Function 4: Provide Emergency Support

FORM	COST	Safety	Optimal Utilizes Existing Resources	Low Workload	Convenience	Increase Sales	Improves Operations	SCORE
Radio	5	5	5	5	5	3	3	31
Data Link	4	1	2	2	2	3	2	16
Satellite-Comm	3	1	2	2	2	3	2	15
	5: Best	1: Worst						

Function Form Selection

- Function 5:
  - Enable System Maintenance & Servicing
- Forms:
  - Human Maintenance & Servicing
  - Computer Automated
  - Computer & Human Party Maintenance Schedule

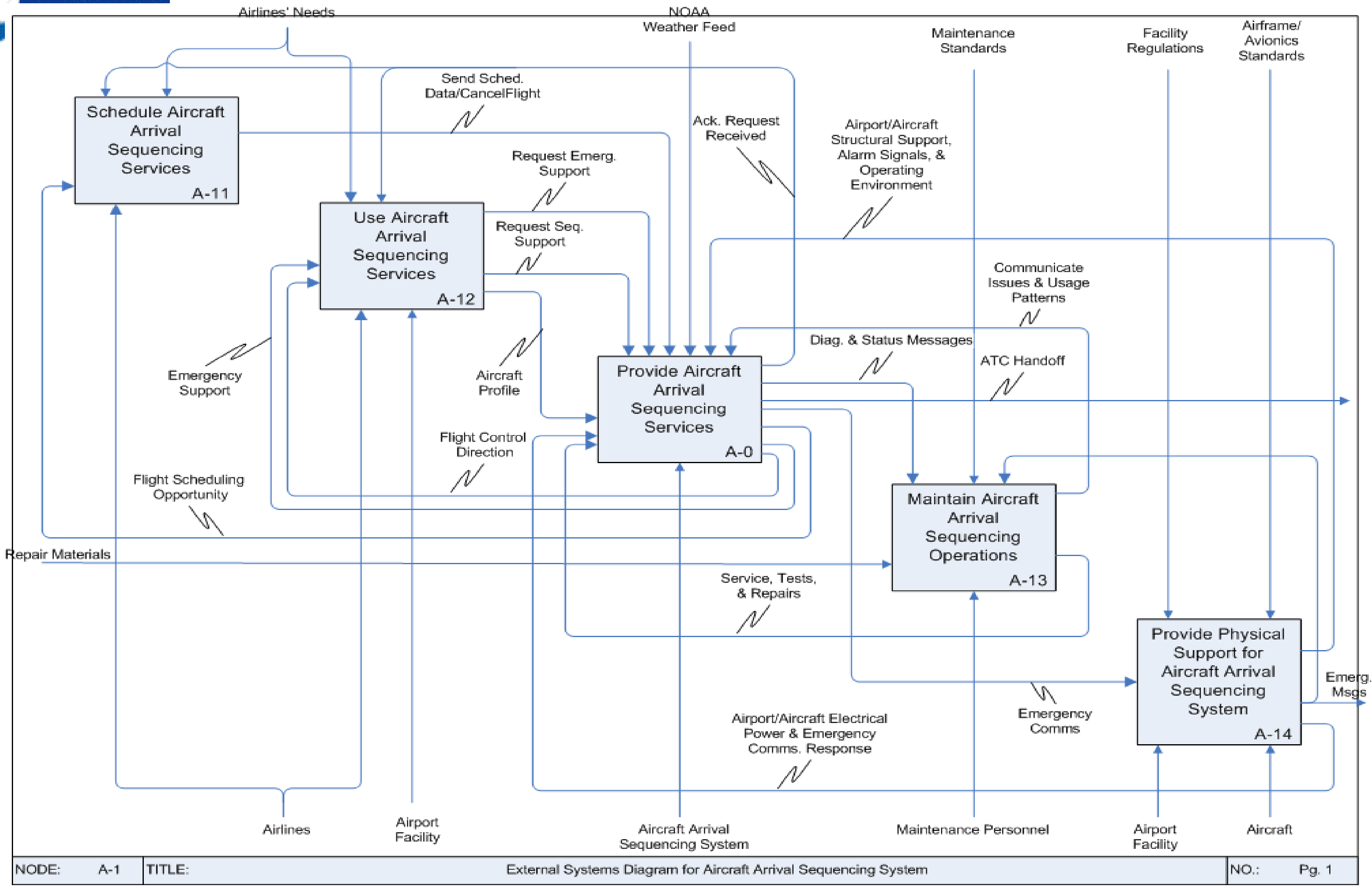
Function Form Selection

- Function 5: Enable System Maintenance & Servicing

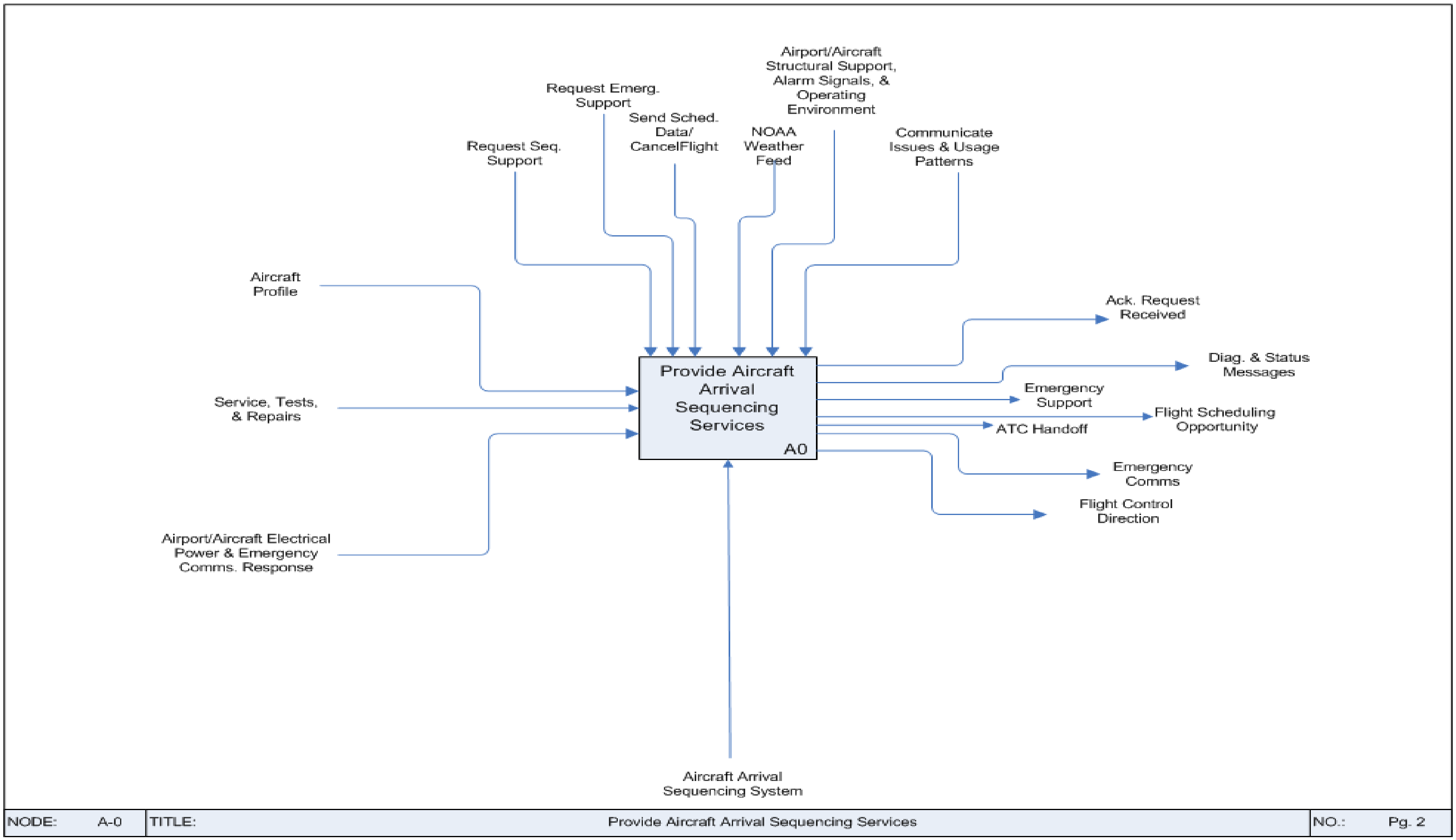
FORM	COST	Safety	Optimal Utilizes Existing Resources	Low Workload	Convenience	Increase Sales	Improves Operations	SCORE
Computer Automated	4	2	4	5	5	3	4	27
Human Maintenance & Servicing	3	3	4	2	2	3	4	21
Computer & Human Maintenance	3	5	4	4	4	3	5	28

5: Best 1: Worst

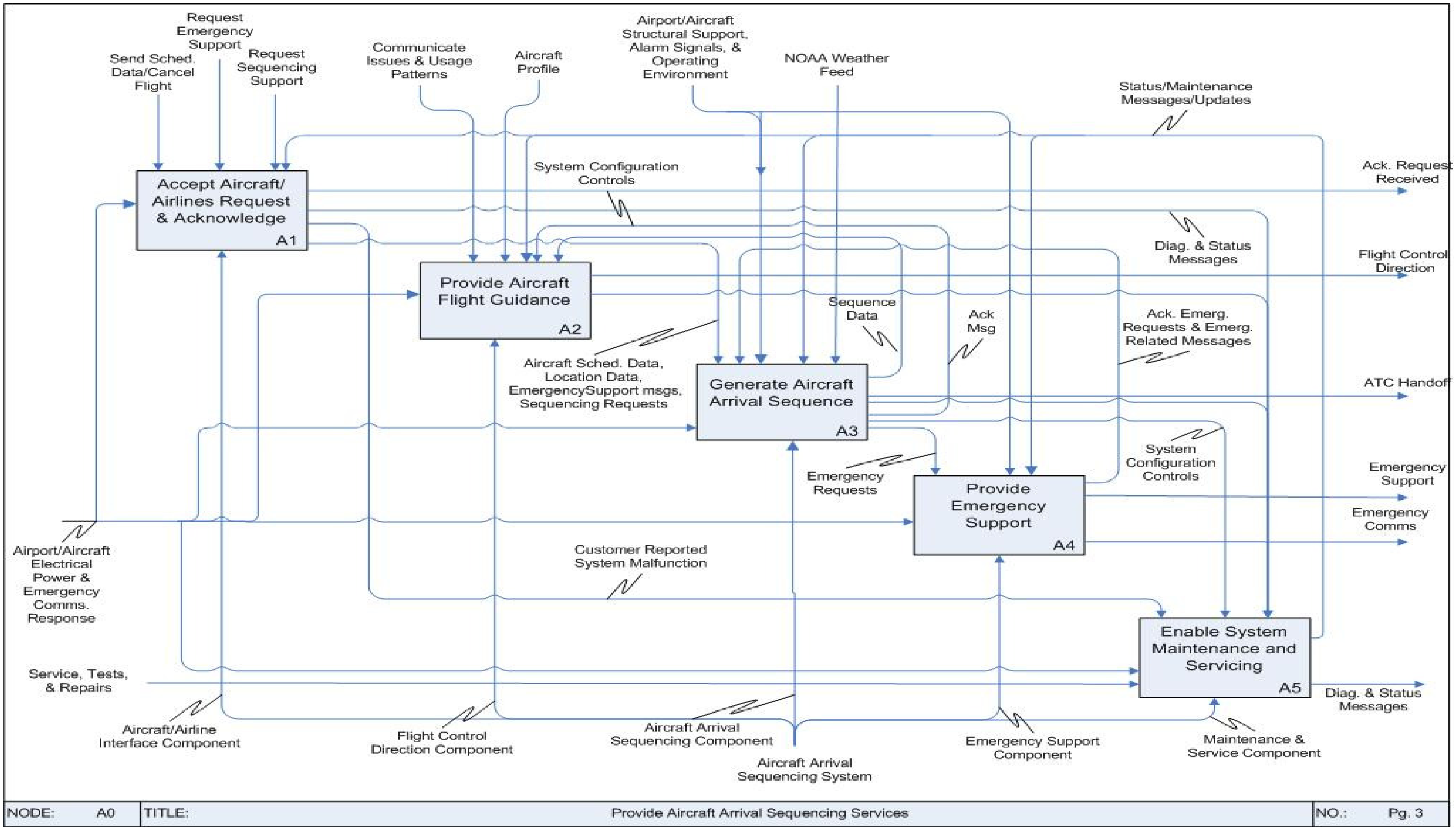
External Systems Diagram



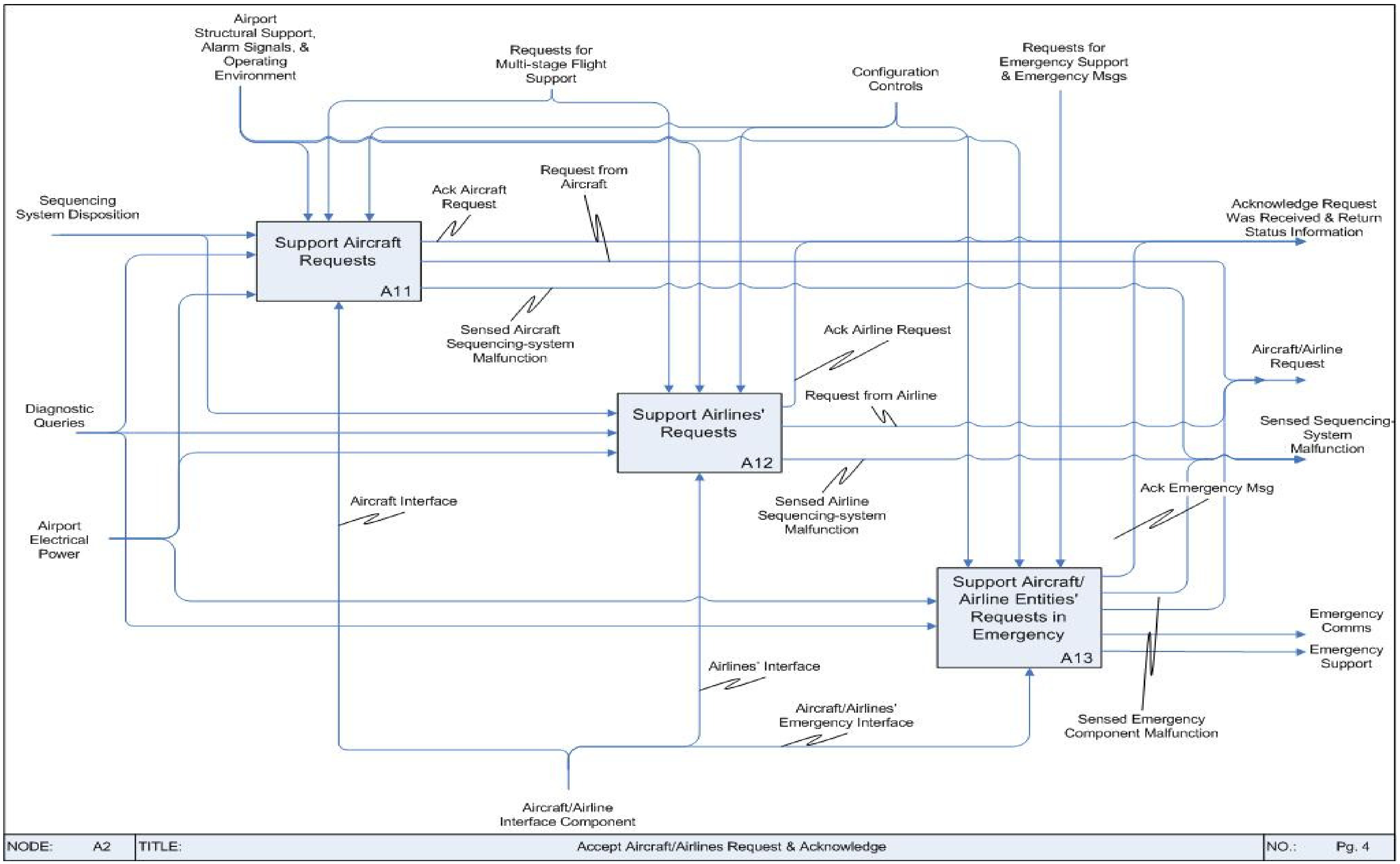
A-0 DIAGRAM


Airport/Aircraft Structural Support, Alarm Signals, & Operating Environment
Request Emerg. Support
Send Sched. Data/ CancelFlight
NOAA Weather Feed
Request Seq. Support
Communicate Issues & Usage Patterns
Aircraft Profile
Ack. Request Received
Diag. & Status Messages
Service, Tests, & Repairs
Provide Aircraft Arrival Sequencing Services
A0
Emergency Support
Flight Scheduling Opportunity
ATC Handoff
Emergency Comms
Flight Control Direction
Airport/Aircraft Electrical Power & Emergency Comms. Response
Aircraft Arrival Sequencing System
NODE: A-0
TITLE: Provide Aircraft Arrival Sequencing Services
NO.: Pg. 2

A0 DIAGRAM

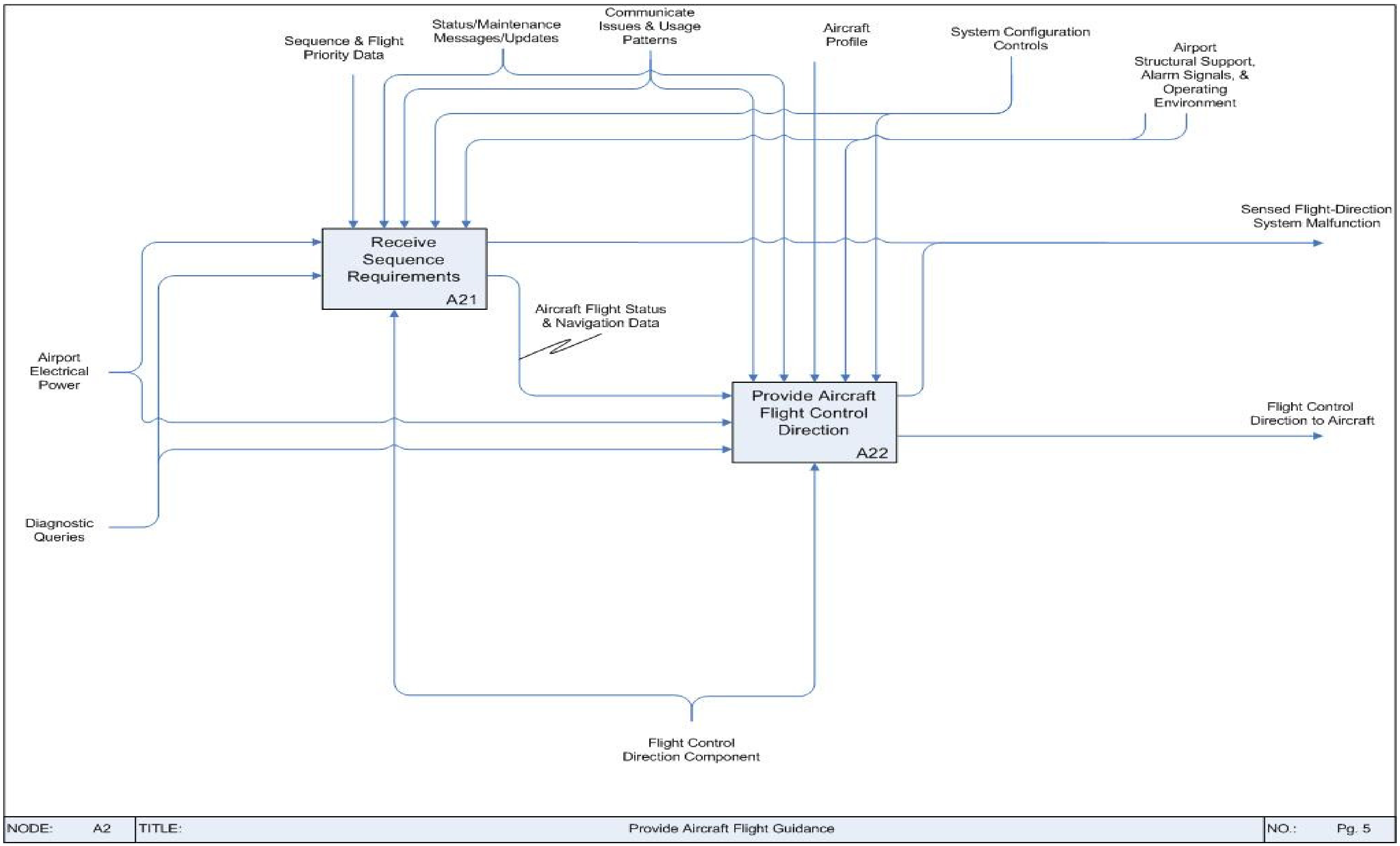

Request Emergency Support
Send Sched. Data/Cancel Flight
Request Sequencing Support
Communicate Issues & Usage Patterns
Aircraft Profile
Airport/Aircraft Structural Support, Alarm Signals, & Operating Environment
NOAA Weather Feed
Status/Maintenance Messages/Updates
Accept Aircraft/ Airlines Request & Acknowledge
A1
System Configuration Controls
Ack. Request Received
Provide Aircraft Flight Guidance
A2
Diag. & Status Messages
Flight Control Direction
Sequence Data
Ack Msg
Ack. Emerg. Requests & Emerg. Related Messages
Aircraft Sched. Data, Location Data, EmergencySupport msgs, Sequencing Requests
Generate Aircraft Arrival Sequence
A3
ATC Handoff
System Configuration Controls
Emergency Requests
Provide Emergency Support
A4
Emergency Support
Emergency Comms
Airport/Aircraft Electrical Power & Emergency Comms. Response
Customer Reported System Malfunction
Enable System Maintenance and Servicing
A5
Service, Tests, & Repairs
Diag. & Status Messages
Aircraft/Airline Interface Component
Flight Control Direction Component
Aircraft Arrival Sequencing Component
Aircraft Arrival Sequencing System
Emergency Support Component
Maintenance & Service Component
NODE: A0
TITLE: Provide Aircraft Arrival Sequencing Services
NO.: Pg. 3

A1 DIAGRAM



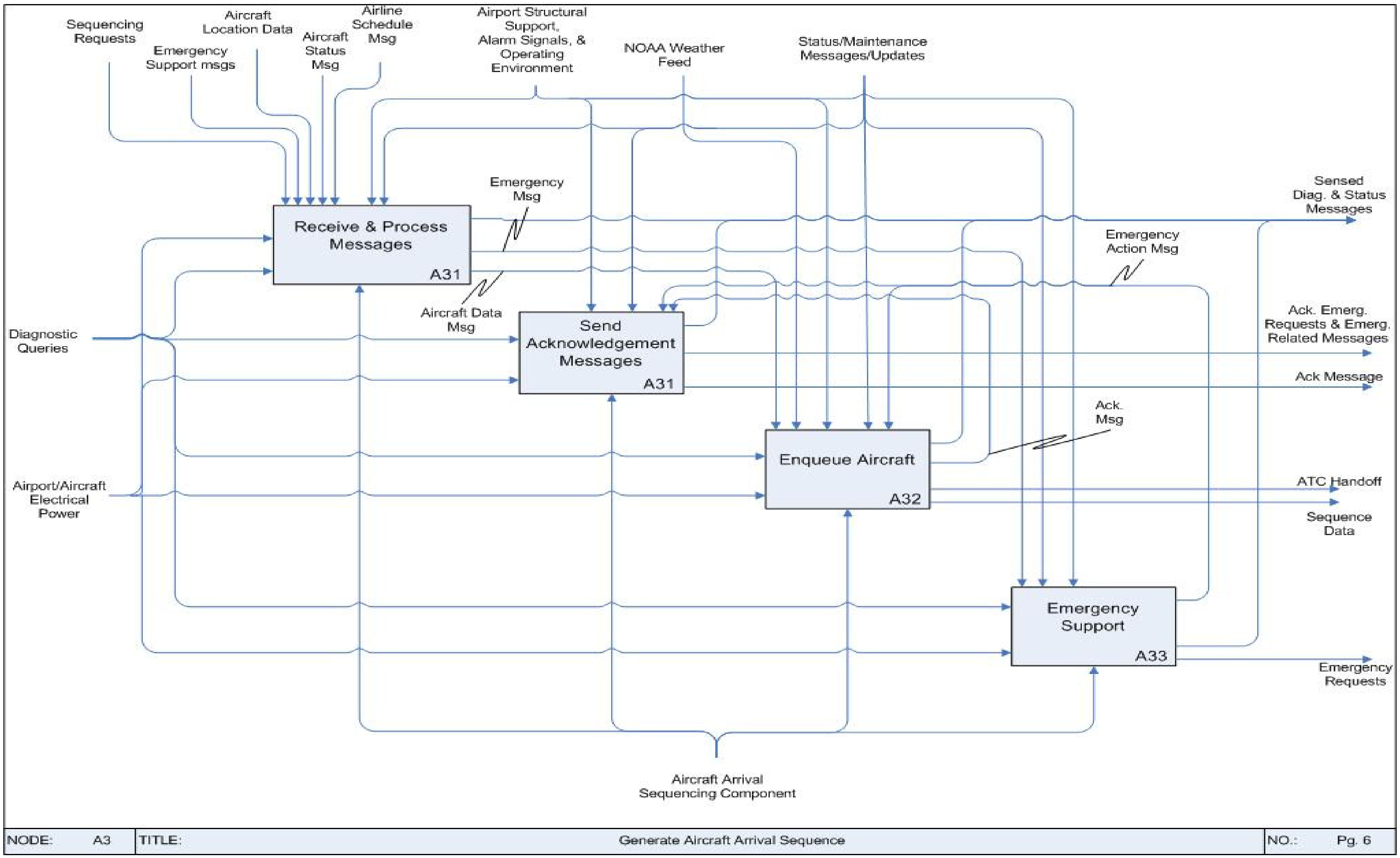
Airport Structural Support, Alarm Signals, & Operating Environment
Requests for Multi-stage Flight Support
Configuration Controls
Requests for Emergency Support & Emergency Msgs
Sequencing System Disposition
Ack Aircraft Request
Request from Aircraft
Acknowledge Request Was Received & Return Status Information
Support Aircraft Requests
A11
Sensed Aircraft Sequencing-system Malfunction
Ack Airline Request
Aircraft/Airline Request
Request from Airline
Diagnostic Queries
Support Airlines' Requests
A12
Sensed Sequencing-System Malfunction
Aircraft Interface
Sensed Airline Sequencing-system Malfunction
Ack Emergency Msg
Airport Electrical Power
Support Aircraft/ Airline Entities' Requests in Emergency
A13
Emergency Comms
Emergency Support
Airlines' Interface
Aircraft/Airlines' Emergency Interface
Sensed Emergency Component Malfunction
Aircraft/Airline Interface Component
NODE: A2
TITLE: Accept Aircraft/Airlines Request & Acknowledge
NO.: Pg. 4

A2 DIAGRAM



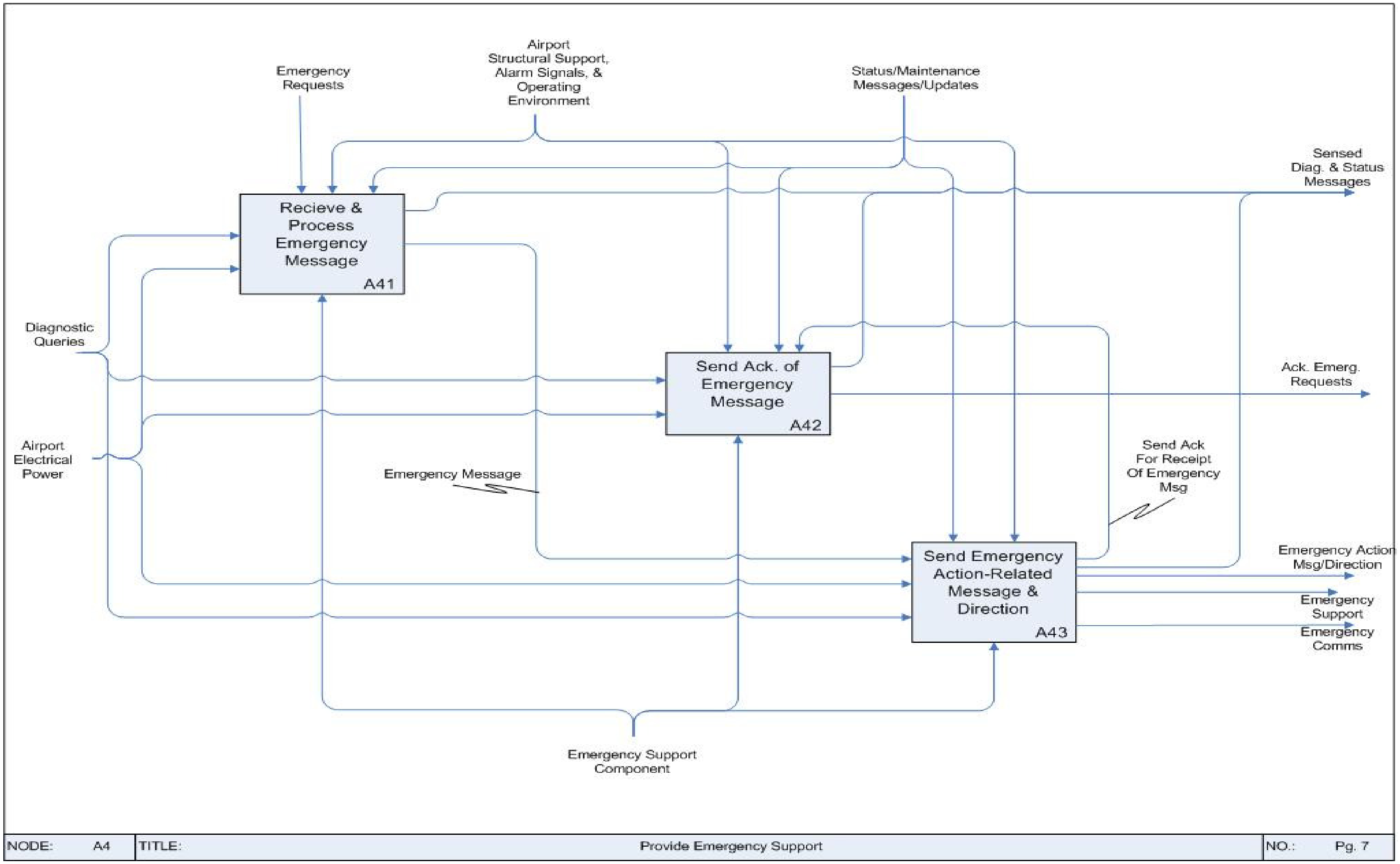
Sequence & Flight Priority Data
Status/Maintenance Messages/Updates
Communicate Issues & Usage Patterns
Aircraft Profile
System Configuration Controls
Airport Structural Support, Alarm Signals, & Operating Environment
Sensed Flight-Direction System Malfunction
Receive Sequence Requirements
A21
Aircraft Flight Status & Navigation Data
Airport Electrical Power
Provide Aircraft Flight Control Direction
A22
Flight Control Direction to Aircraft
Diagnostic Queries
Flight Control Direction Component
NODE: A2
TITLE: Provide Aircraft Flight Guidance
NO.: Pg. 5

A3 DIAGRAM

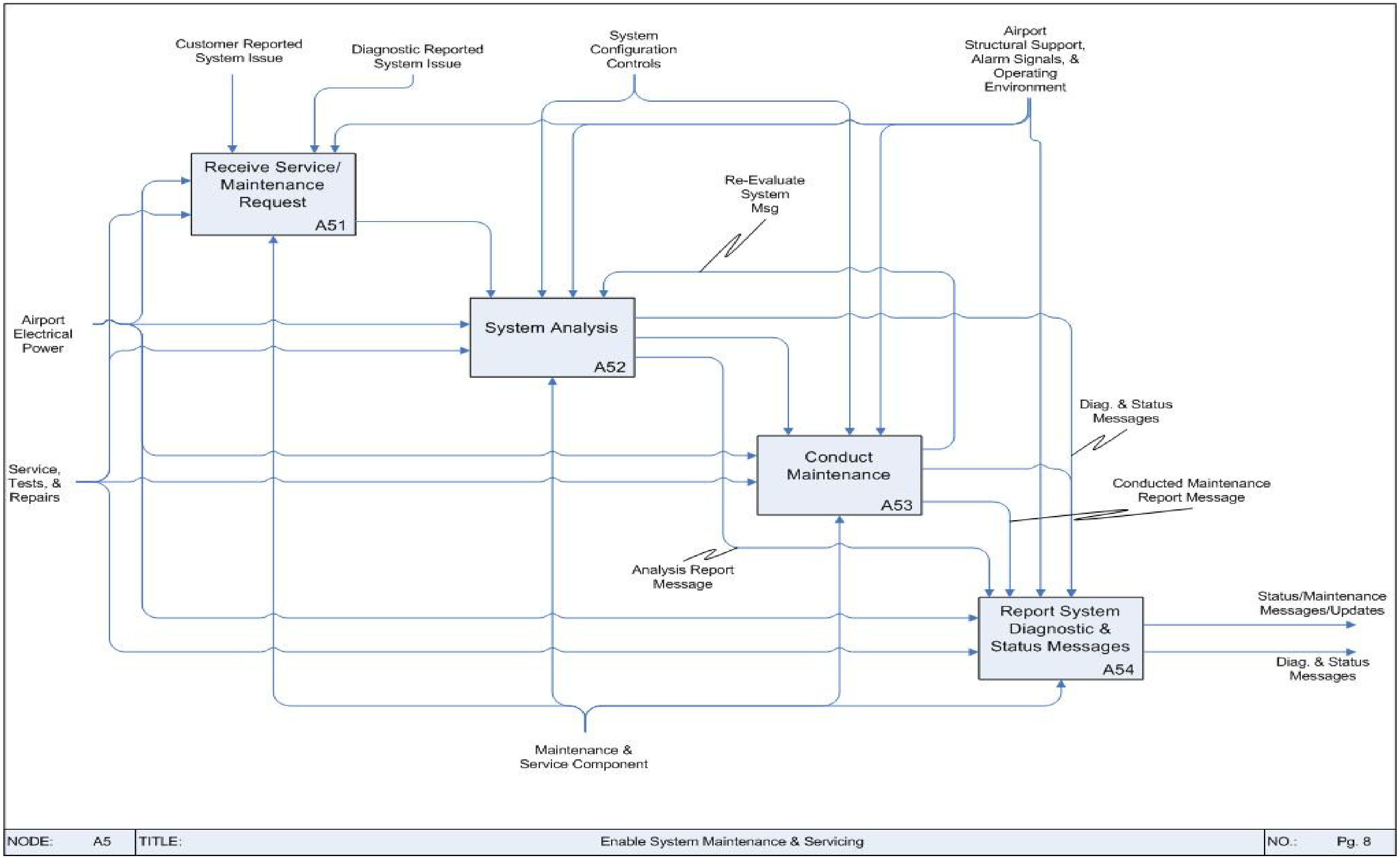


Sequencing Requests
Aircraft Location Data
Emergency Support msgs
Aircraft Status Msg
Airline Schedule Msg
Airport Structural Support, Alarm Signals, & Operating Environment
NOAA Weather Feed
Status/Maintenance Messages/Updates
Emergency Msg
Receive & Process Messages
A31
Aircraft Data Msg
Send Acknowledgement Messages
A31
Diagnostic Queries
Airport/Aircraft Electrical Power
Enqueue Aircraft
A32
Emergency Support
A33
Emergency Action Msg
Sensed Diag. & Status Messages
Ack. Emerg. Requests & Emerg. Related Messages
Ack Message
Ack. Msg
ATC Handoff
Sequence Data
Emergency Requests
Aircraft Arrival Sequencing Component
NODE: A3
TITLE: Generate Aircraft Arrival Sequence
NO.: Pg. 6

A4 DIAGRAM


Emergency Requests
Airport Structural Support, Alarm Signals, & Operating Environment
Status/Maintenance Messages/Updates
Sensed Diag. & Status Messages
Recieve & Process Emergency Message
A41
Diagnostic Queries
Send Ack. of Emergency Message
A42
Ack. Emerg. Requests
Airport Electrical Power
Emergency Message
Send Ack For Receipt Of Emergency Msg
Send Emergency Action-Related Message & Direction
A43
Emergency Action Msg/Direction
Emergency Support
Emergency Comms
Emergency Support Component
NODE: A4
TITLE: Provide Emergency Support
NO.: Pg. 7

A5 DIAGRAM

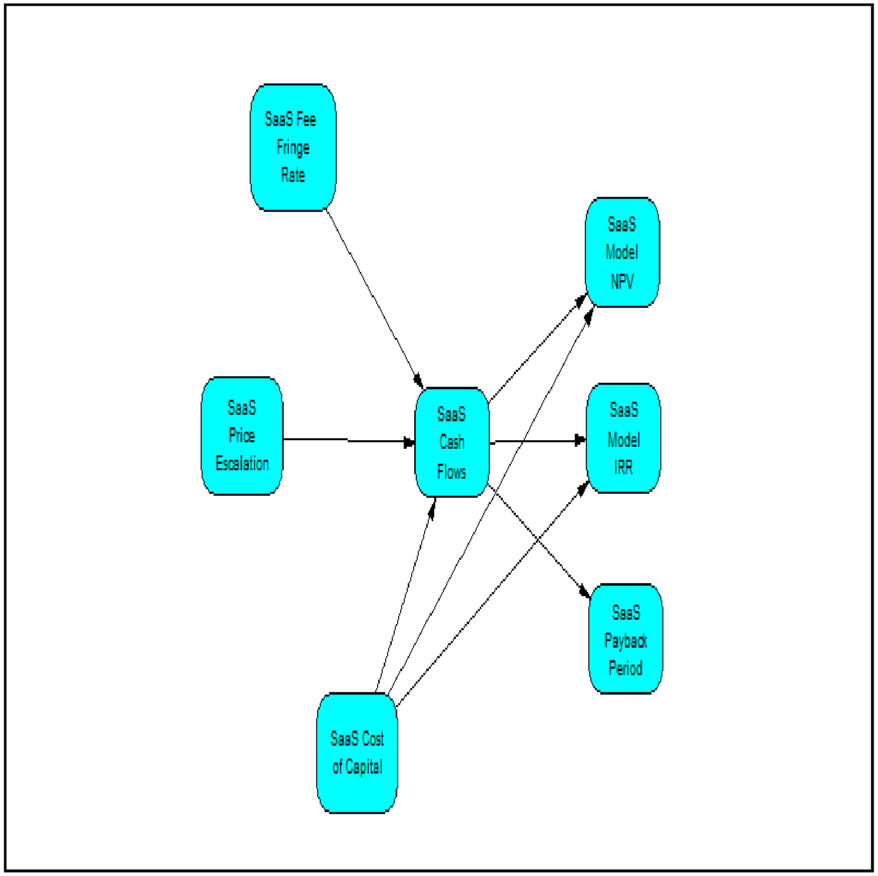

Customer Reported System Issue
Diagnostic Reported System Issue
System Configuration Controls
Airport Structural Support, Alarm Signals, & Operating Environment
Receive Service/ Maintenance Request
A51
Re-Evaluate System Msg
Airport Electrical Power
System Analysis
A52
Diag. & Status Messages
Service, Tests, & Repairs
Conduct Maintenance
A53
Conducted Maintenance Report Message
Analysis Report Message
Report System Diagnostic & Status Messages
A54
Status/Maintenance Messages/Updates
Diag. & Status Messages
Maintenance & Service Component
NODE: A5
TITLE: Enable System Maintenance & Servicing
NO.: Pg. 8

Team Dynamics

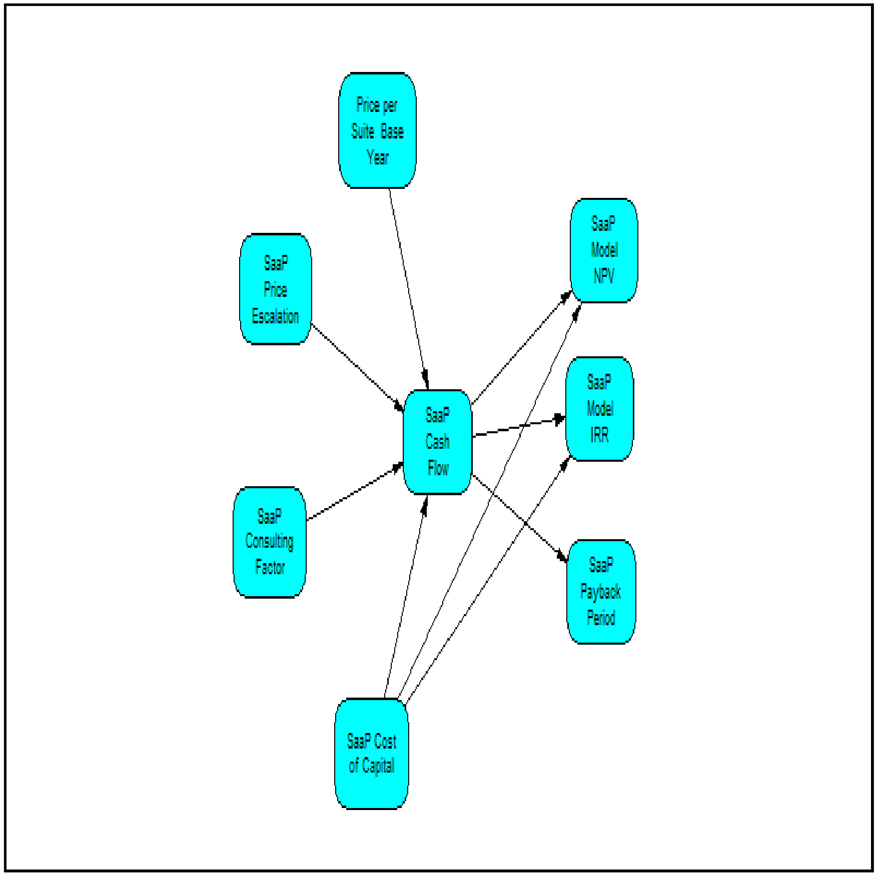
- Team worked via email and weekly team meetings
- Team collaborated and communicated via live communicator
- Fortunate to have experienced individuals in:
  - Systems Engineering
  - Operational Research
  - Web Design
  - Subject Matter Experts
  - ARENA
  - Matlab

5) Influence Diagrams

SaaS Business Model

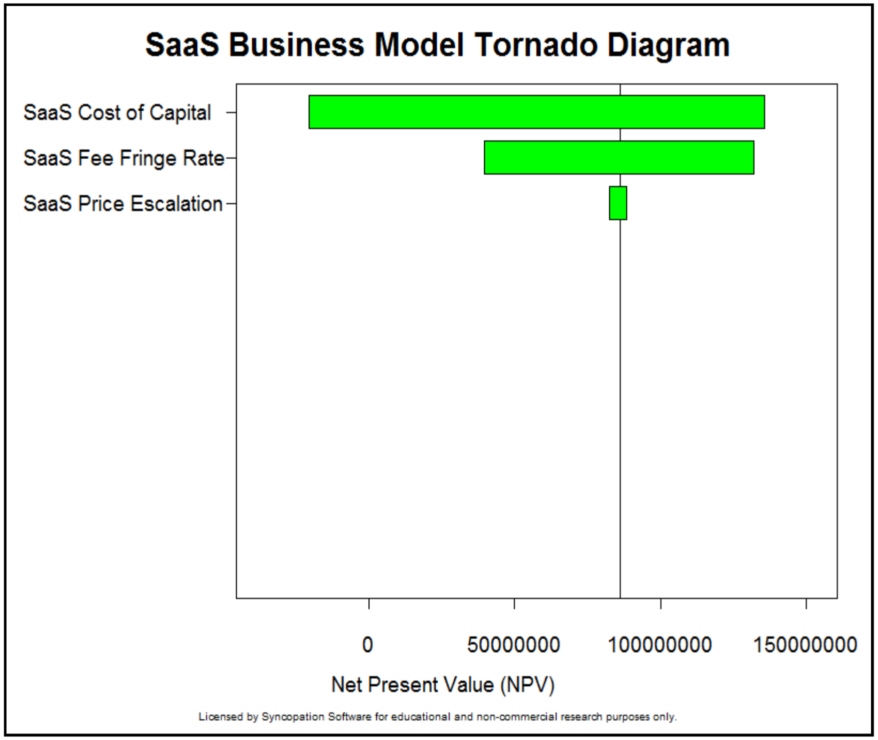


SaaP Business Model

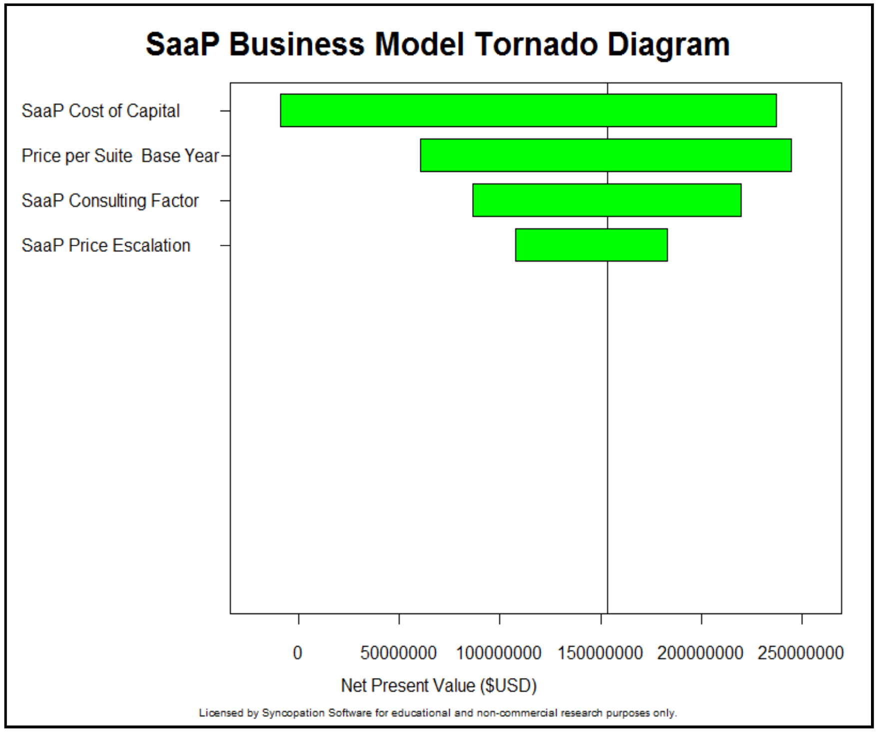


5) Tornado Diagrams

SaaS Business Model



SaaP Business Model

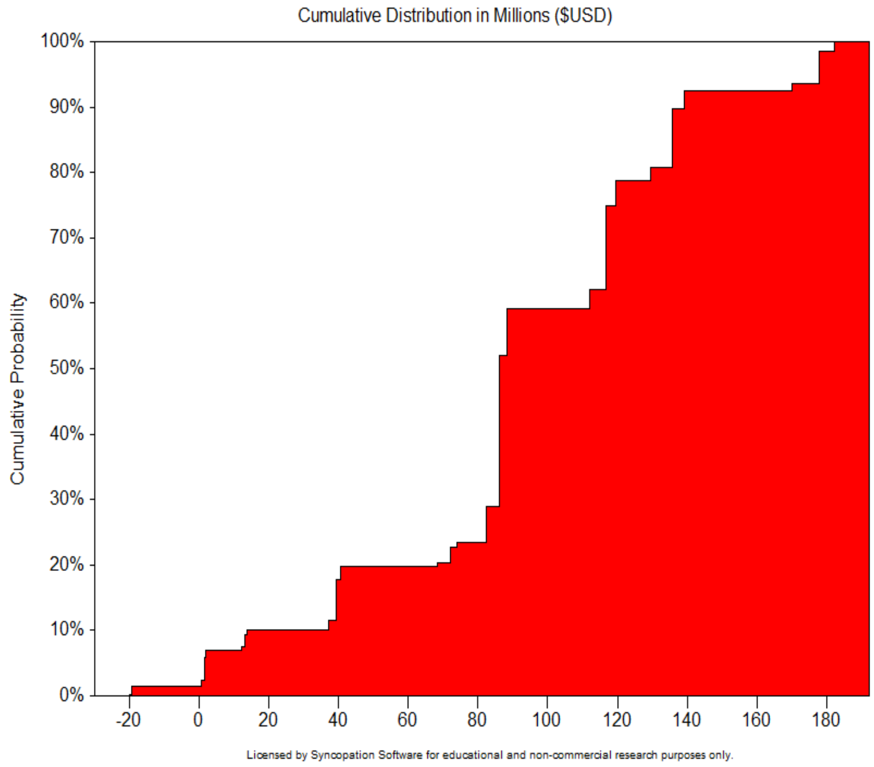


Decision Tree Parameters

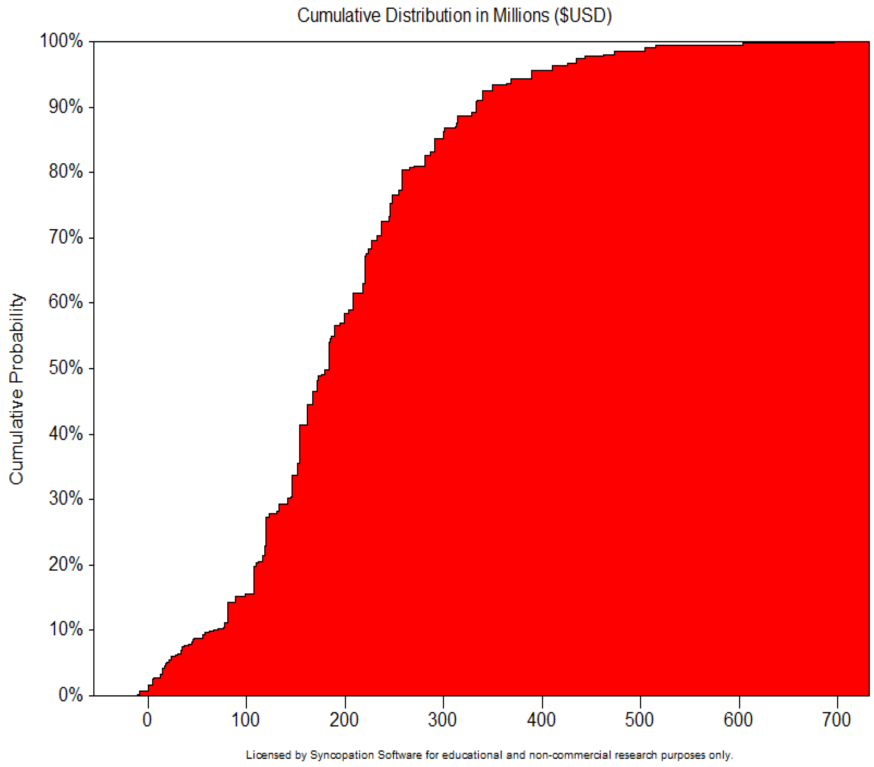
	Cost of Capital			Price Escalation			Fee & Fringe Rate			System Price			Consulting Factor		
	Scenario	Value	Probability	Scenario	Value	Probability	Scenario	Value	Probability	Scenario	Value	Probability	Scenario	Value	Probability
SaaS	Low	5.0%	25.0%	Low	1.03	30.0%	Low	30.0%	15.0%						
SaaS	Nominal	10.0%	65.0%	Nominal	1.075	40.0%	Nominal	45.0%	55.0%						
SaaS	High	30.0%	10.0%	High	1.1	30.0%	High	55.0%	30.0%						
SaaS															
SaaP	Low	5.0%	25.0%	Low	1.03	30.0%				Monopoly	$1,000,000.00	10.0%	Low	0.25	30.0%
SaaP	Nominal	10.0%	65.0%	Nominal	1.075	40.0%				Aggressive	$ 750,000.00	25.0%	Nominal	0.35	40.0%
SaaP	High	30.0%	10.0%	High	1.1	30.0%				Fair	$ 600,000.00	55.0%	High	0.55	30.0%
SaaP										Competitive	$ 500,000.00	10.0%			

NPV Profile Comparison

SaaS Business Model

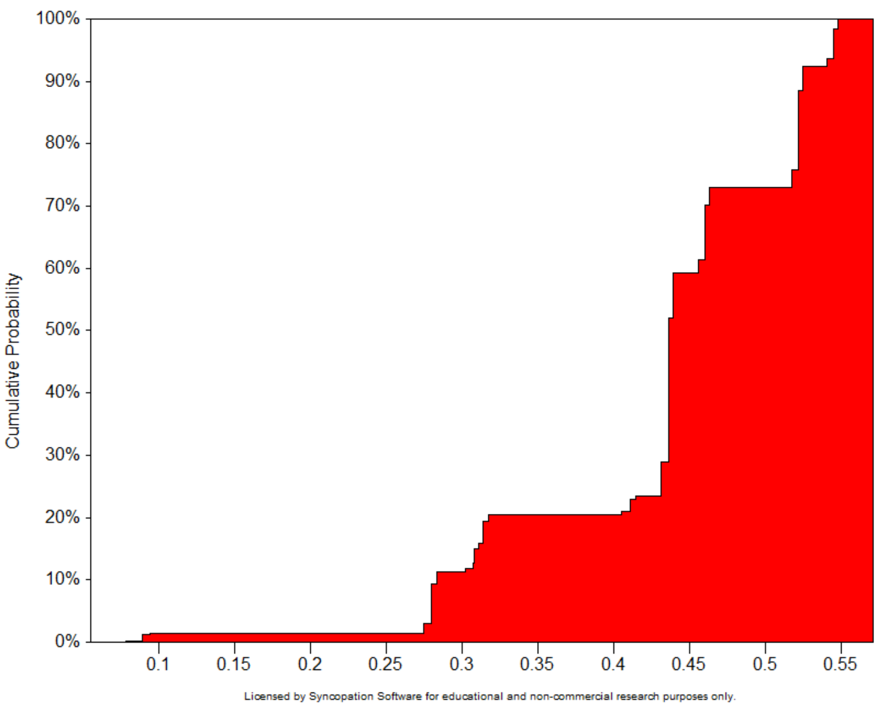


SaaP Business Model

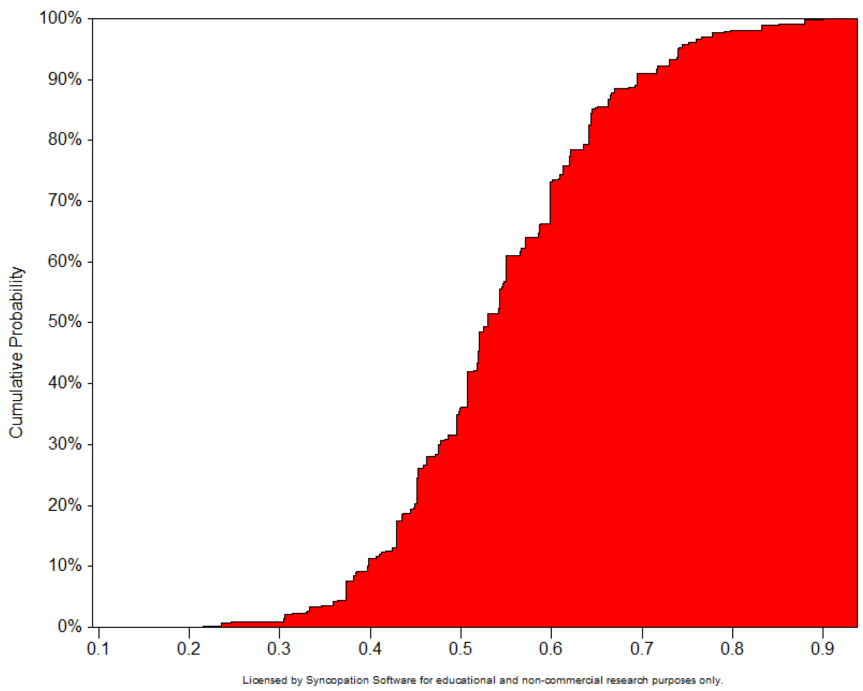


IRR Profile Comparison

SaaS Business Model

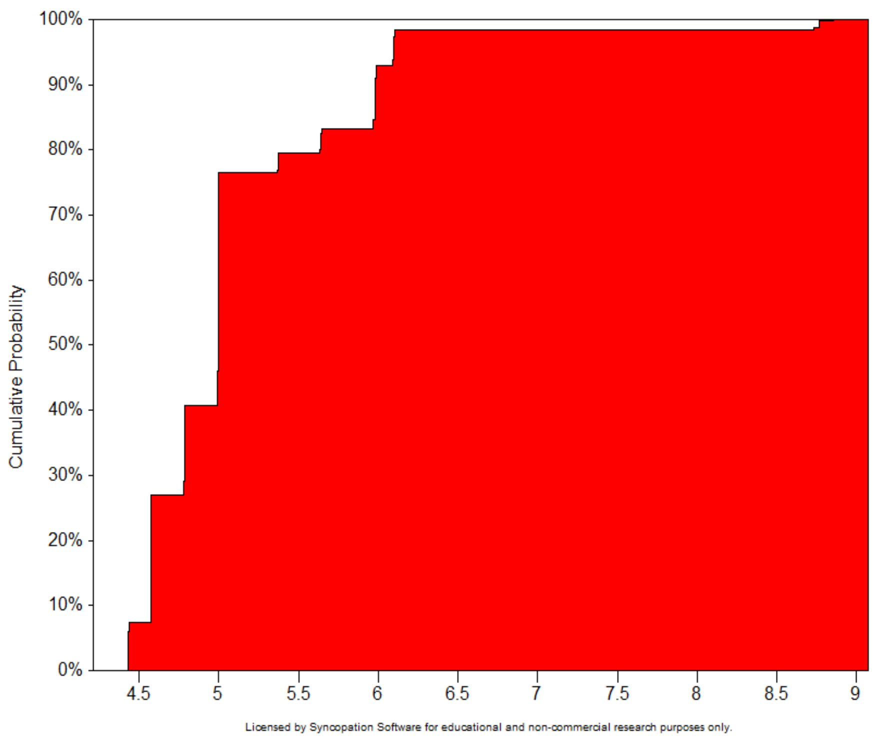


SaaP Business Model

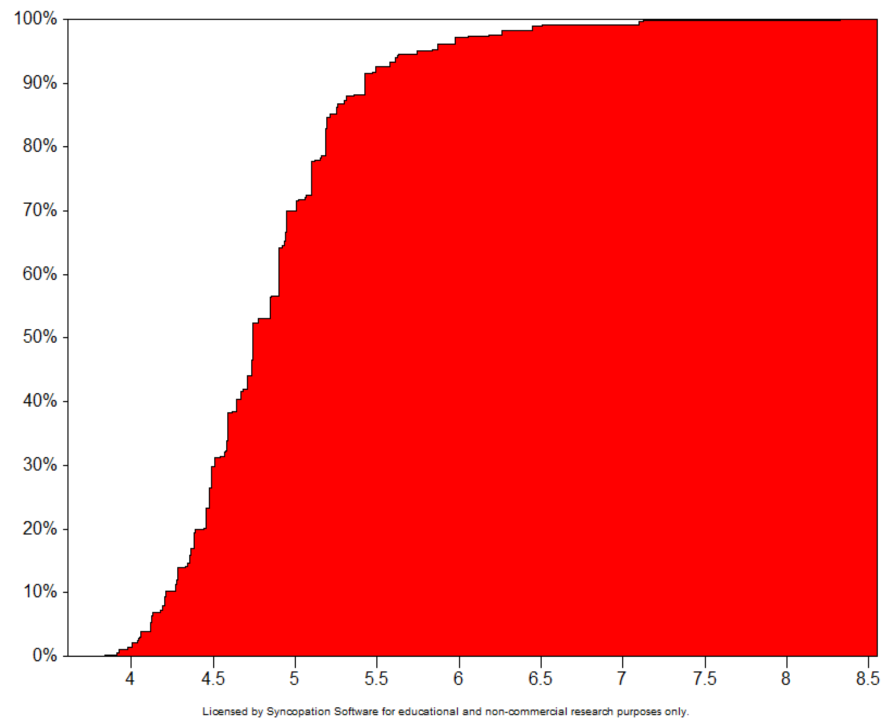


Payback Period Comparison

SaaS Business Model



SaaP Business Model



Effective Payback Period is approximately 3 years in both models because revenue is not anticipated until Year 3.