Taxi Fleet Management System with Augmented Passenger Safety

SYSTEMS ENGINEERING MASTERS PROJECT PRESENTATION

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Biography

I am Prashant Sarpatwari. I work as Principal Engineer with Broadcom India in design engineering of ASICs for L2/L3 Ethernet switches. I have around 15 years of work experience in chip design for wired/ wireless communication industry and have earlier worked at Conexant Systems, Paxonet Communications, HBL Nife Power Systems in various positions in design engineering. I also worked on Radar system design for about 1.5 years. I have Bachelor of Engineering (B.E.) in Electronics and Telecommunications degree from Government College of Engineering Aurangabad, India.

I live in Bangalore, India with my wife and two daughters.

Recently INCOSE published my profile in it's *25@25 Spotlight Profiles*

http://www.incose.org/docs/default-source/memberspotlight/25@25-m2-prashant-sarpatwari.pdf?sfvrsn=2

System Introduction

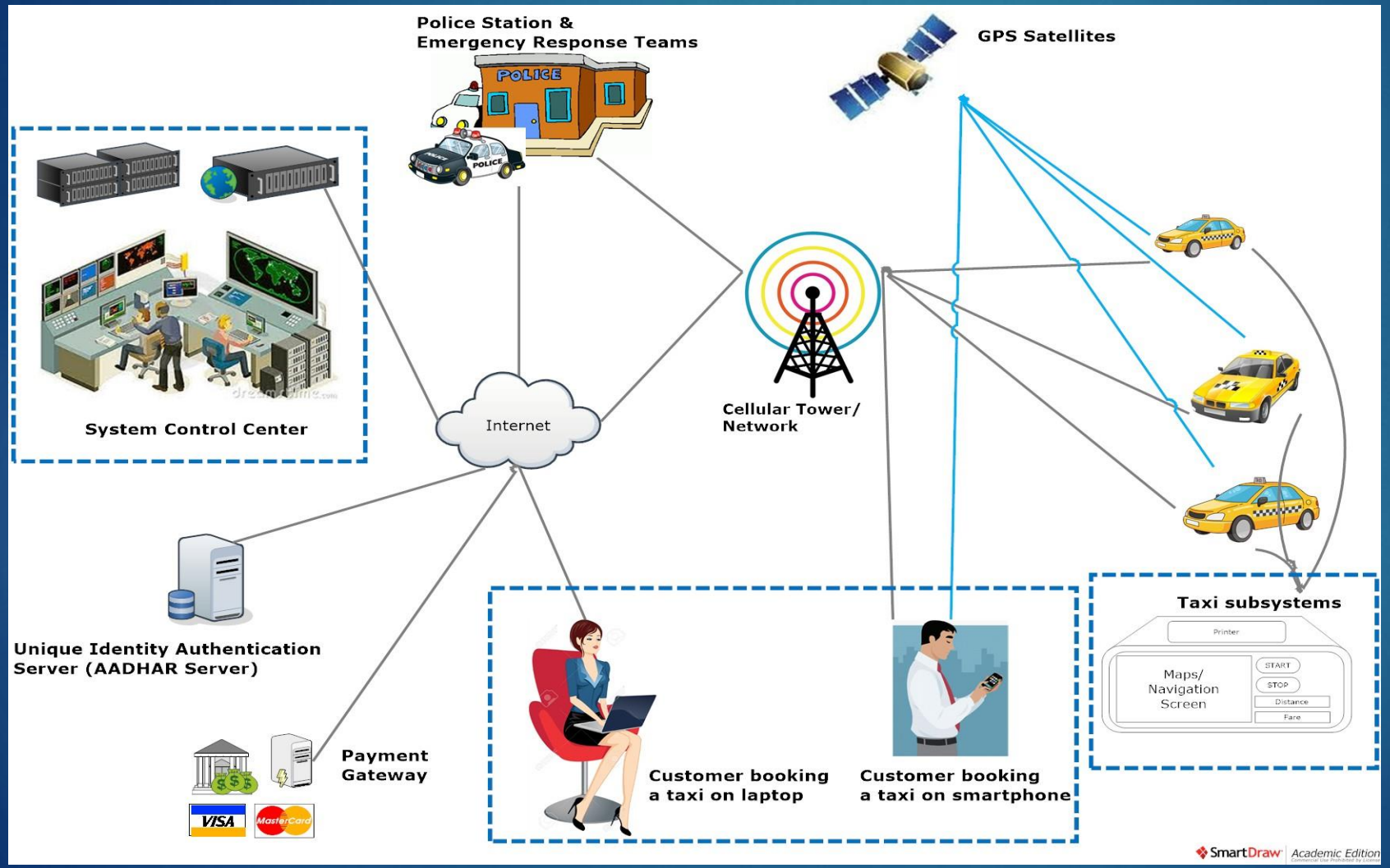
- Taxi Fleet Management with Augmented Passenger Safety (TFMwAPS) System manages a fleet of taxis and enhances safety of travelling passenger

- Salient features
  - GPS based tracking of all taxis
  - Periodic driver Identity Check
  - Passenger can raise Emergency Alert
  - Simple & Quick booking
    - GPS based pickup location
    - One touch "Call Taxi"
    - Light and fast Taxi Booking Application
  - Intelligent Taxi Allocation to customers
  - Minimal Operator Involvement
  - Multiple Payment Options
  - Accurate Billing
  - High System Availability & Reliability
  - Up to 3000 taxis in fleet
  - Coverage Area of radius 40 km

Need for System

- Unauthorized drivers and related crimes
  - No way to identify and track the criminal
- Overcharging, mugging, crimes against women
- No tracking of taxis
  - Late support to victims
- Existing taxi operators and their systems are not Reliable
  - May not honor pickup commitment
  - Smartphone booking applications not reliable - dependent on Internet connection
  - Many small, area-wise operators with different contact methods/ phone numbers
  - Customer may not know about Available taxi in vicinity, and vice versa
- Existing systems have poor Availability
  - Booking systems may be overloaded in peak hours, out-of-service at odd times
- Taxi Operator Companies not able to use their fleet efficiently

Concept of Operations (CONOPS)



Three subsystems:

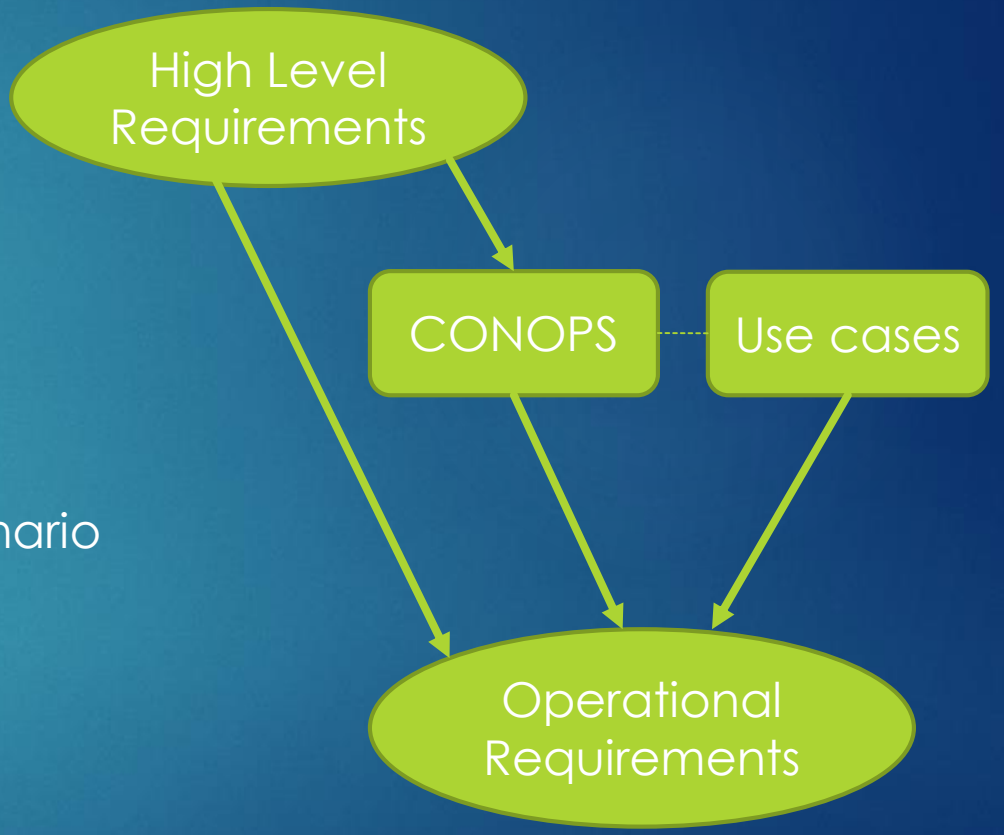
1. Control Center Subsystem
2. Taxi Booking Subsystem
3. Taxi Subsystem

External entities/ systems:

1. GPS Satellites
2. Unique Identity Server
3. Police/ emergency systems
4. Cellular comm network
5. Human Customer users
6. Human Taxi driver
7. Human Operators
8. Environment

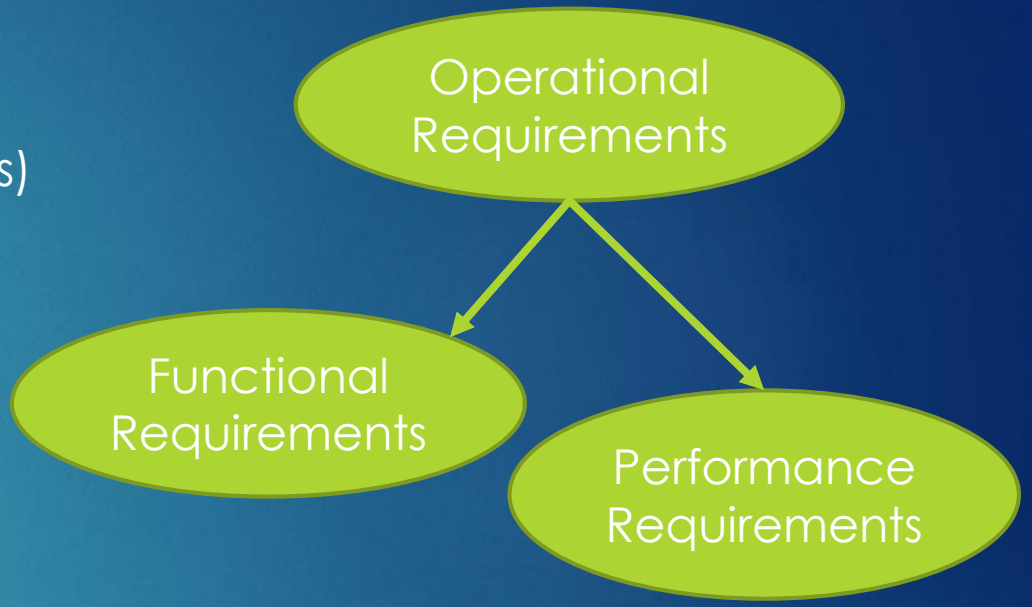
Concept of Operations (CONOPS)

- Normal operation (Baseline Scenario) –
  - Customer calls a taxi
  - Control Center finds an available taxi
  - Assigned taxi drives to pickup customer
  - Customer is driven to destination and trip ends
- Other Use Cases
  - Rogue Taxi Driver – Passenger Emergency Scenario
  - Unauthorized Driver Scenario
  - Bad Weather Scenario

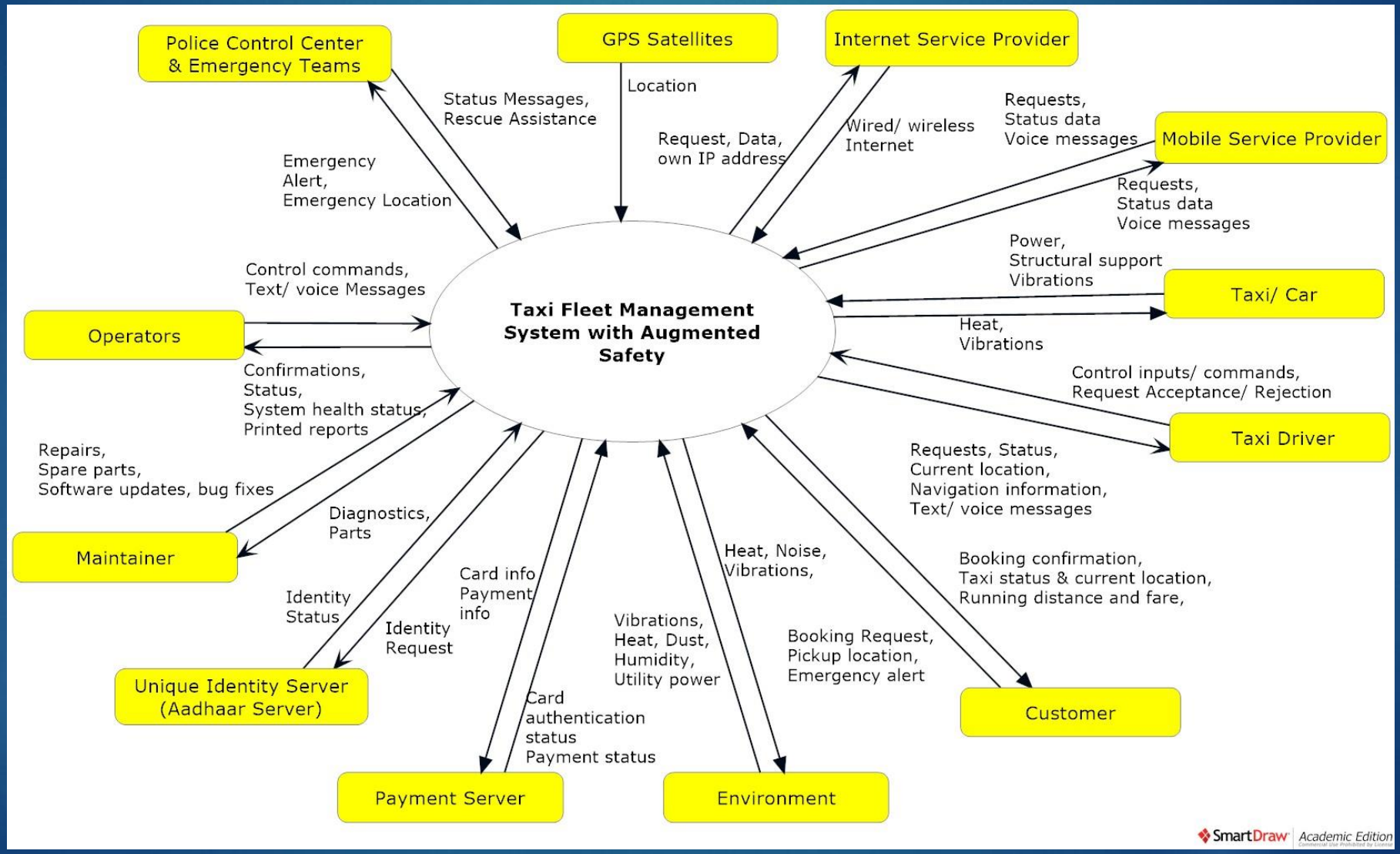


Requirements

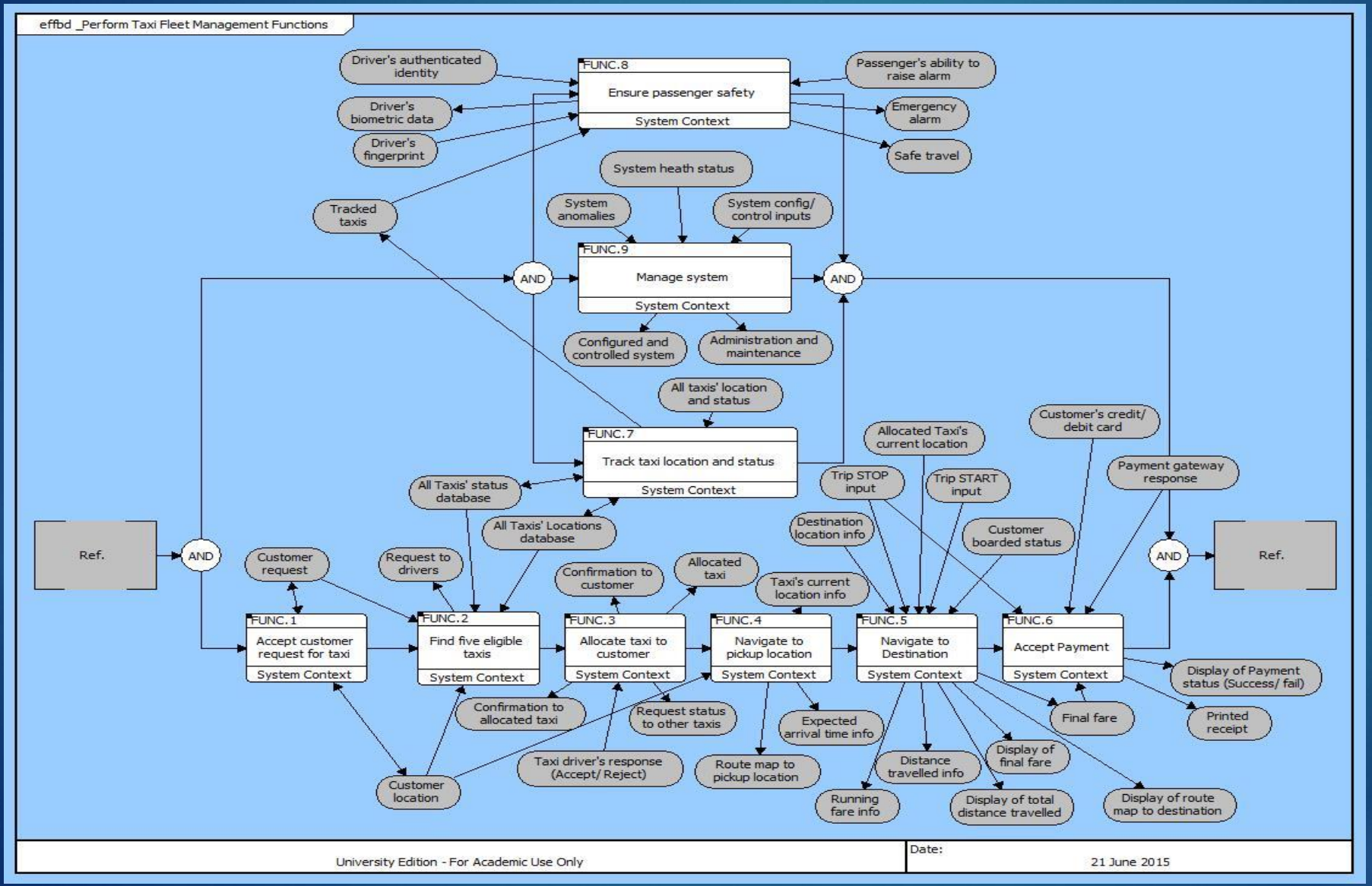
- Requirements generated from
  - Informal interviews with users (customers, taxi drivers)
  - Internet research
  - Project Concept, CONOPS, Use cases
  - Major external systems and major users interfaces
  - Existing systems
  - Scale of operation, Operating conditions
  - SMEs
- Prioritization of needs and requirements

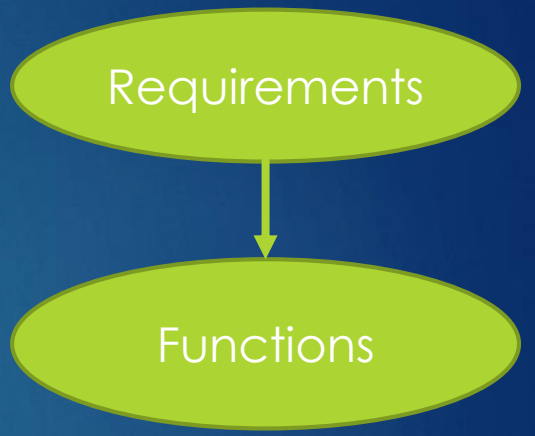


Functional Concept – Context Diagram



Functional Concept – Block Diagram



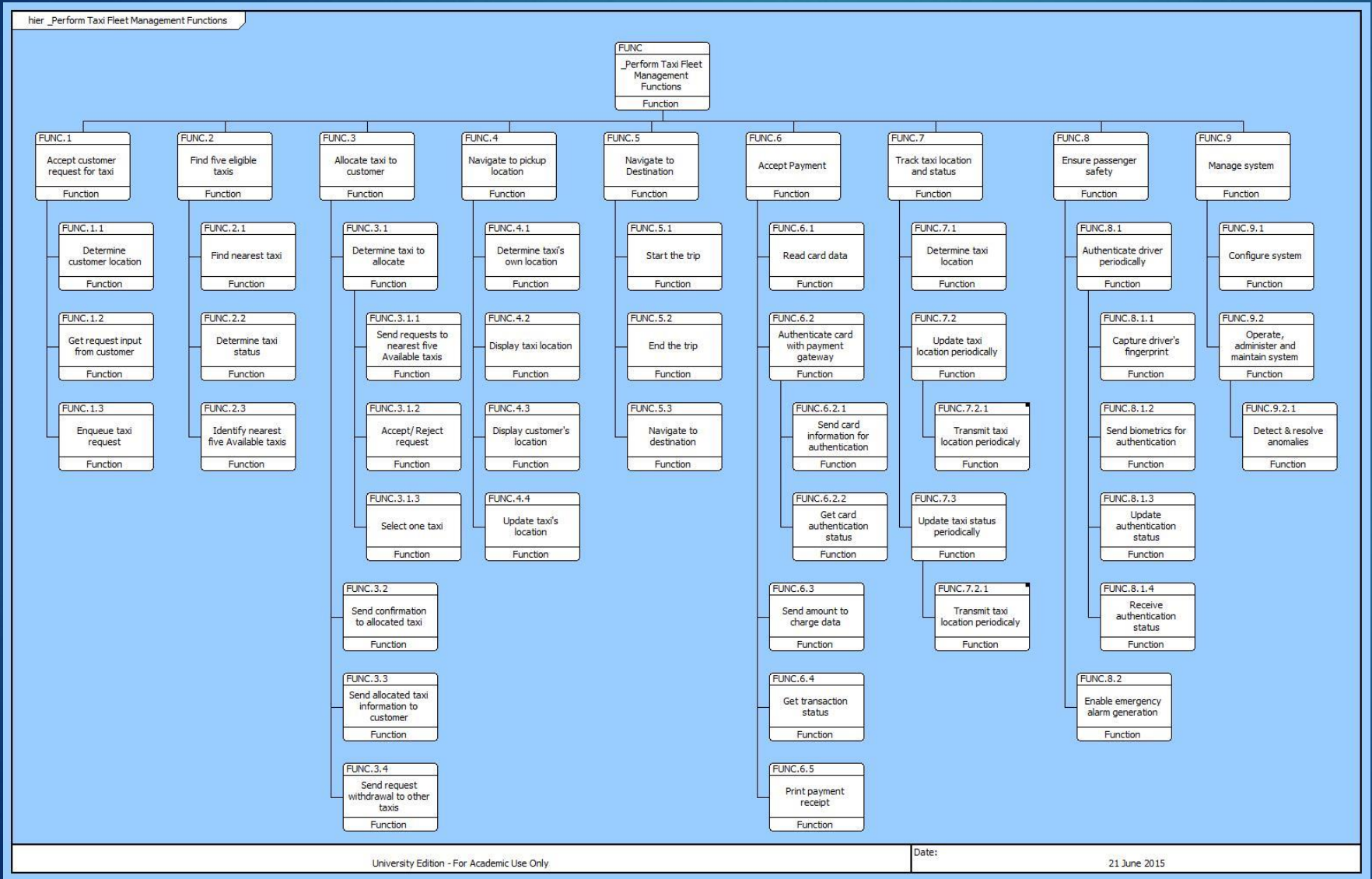


- Four main Activities:

1. Taxi booking and Allocation
2. Taxi trip
2. Taxi tracking & Safety
4. System management

- Functions traced to Requirements

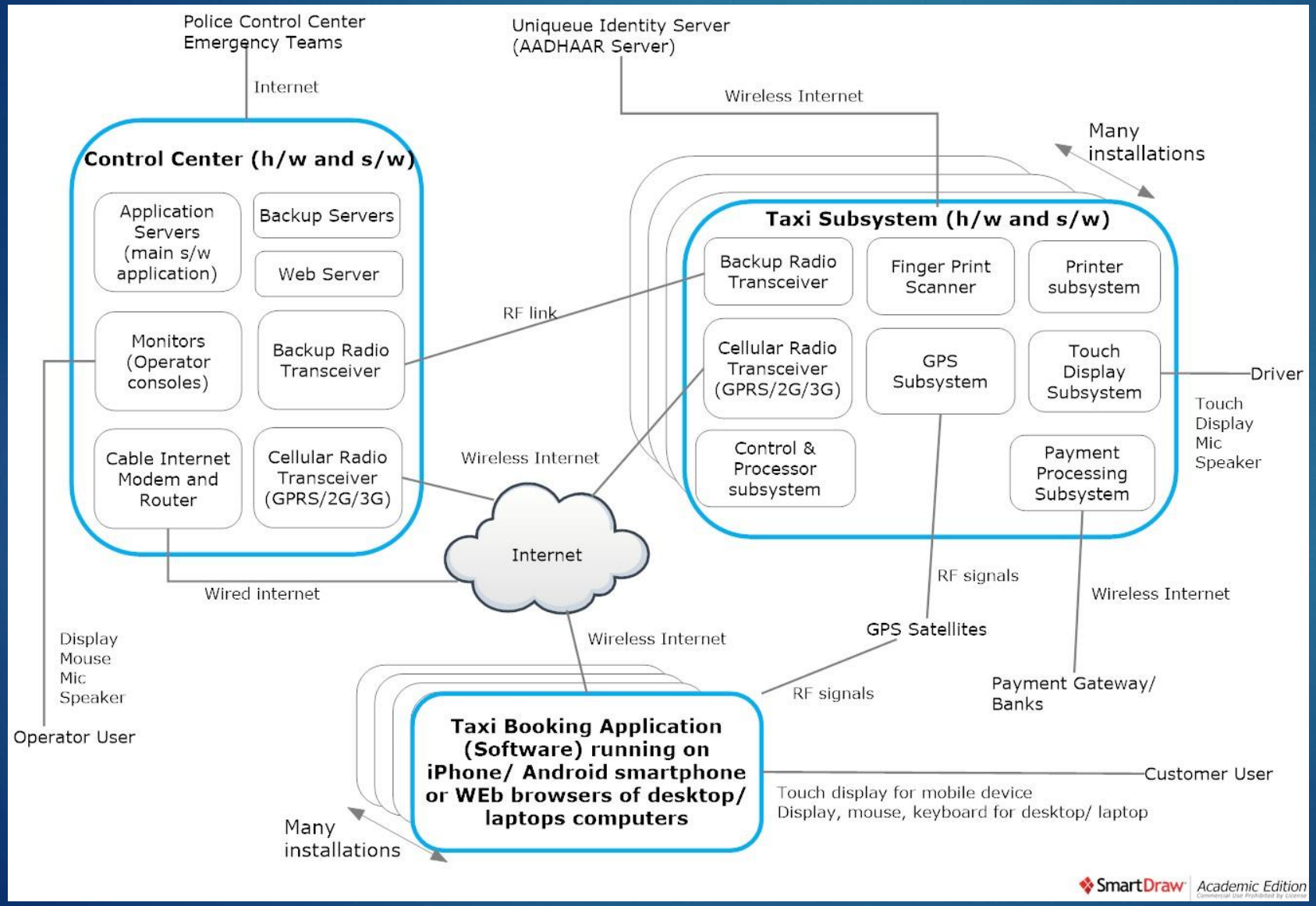
Functions Hierarchy



Nine Top Level Functions

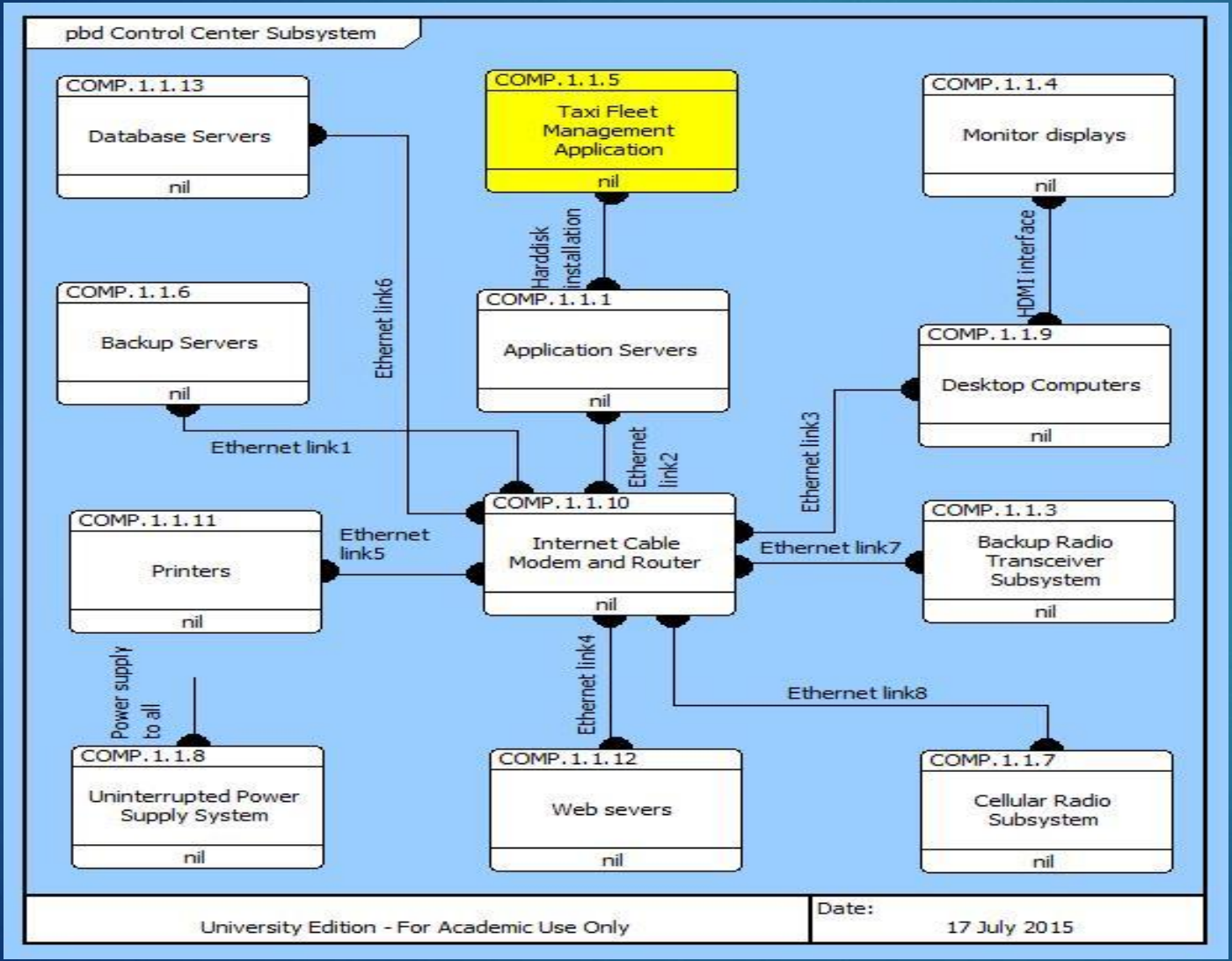
1. Accept customer request for taxi
2. Find five eligible taxis
3. Allocate taxi to customer
4. Navigate to pickup location
5. Navigate to destination
6. Accept payment
7. Track taxi location and status
8. Ensure passenger safety
9. Manage system

Physical Concept – Top Level



- Three subsystems
- Control Center and Taxi Subsystems communicate over wireless Internet or backup RF link
- Control Center and Taxi Booking Subsystems communicate over Internet

Physical Concept – Control Center PBD



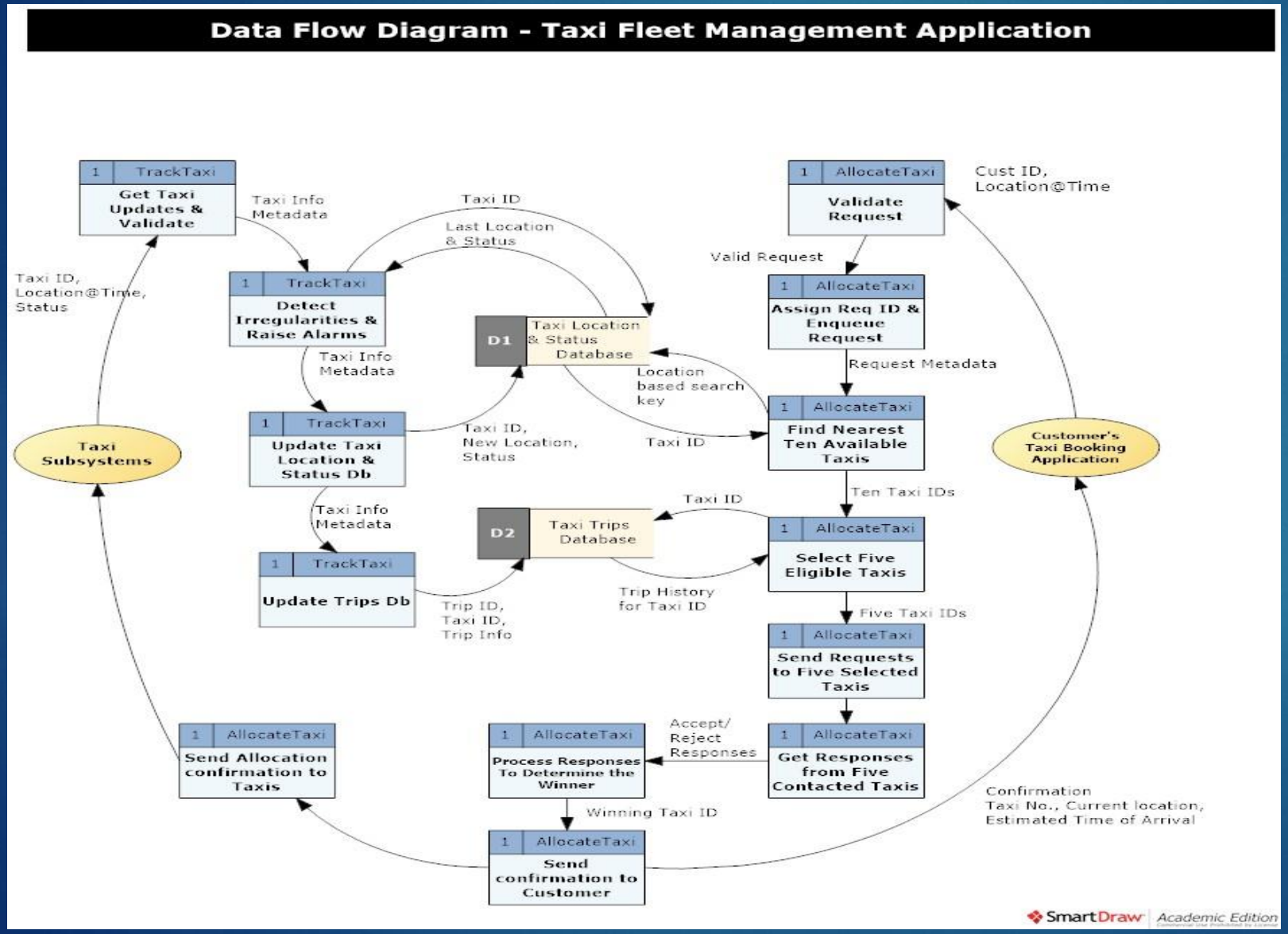
Functions

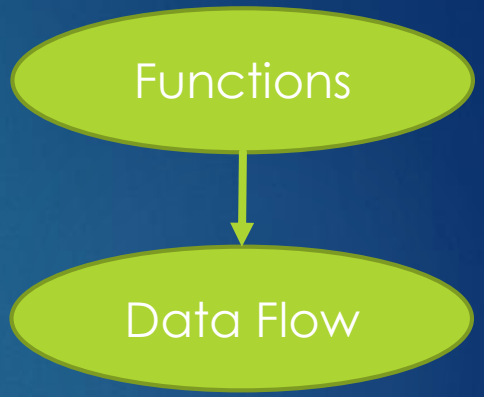
Components

- Control Center Subsystems
1. Application Servers
2. Taxi Fleet Mgmt Application S/W
3. Web Servers
4. Database servers
5. Desktop computers
6. Monitor displays
7. Cellular Radio Subsystem
8. Backup radio transceiver Subsystem
9. Internet Cable Modem and Router
10. Printer
11. Backup servers

- Client Server Architecture
- Components Traced to Functions

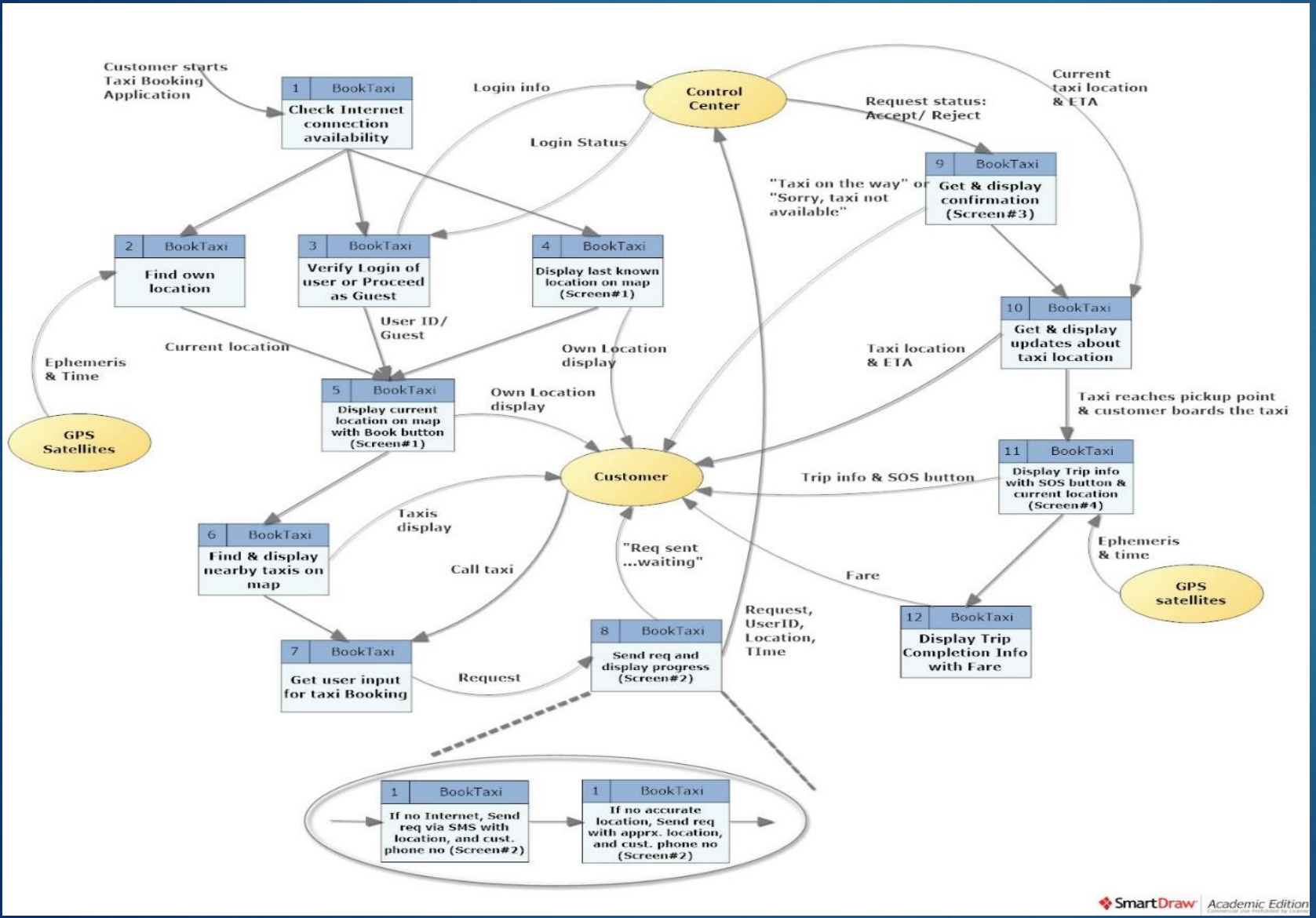
Physical Concept – Control Center Data Flow Diagam





- Taxi Fleet Mgmt Application Software
  Implements major functions
- Desktop Client Application implements - OAM functions such as report generation and printing, maintenance, backup, configuration and control.

Physical Concept – Taxi Booking Subsystem Data Flow



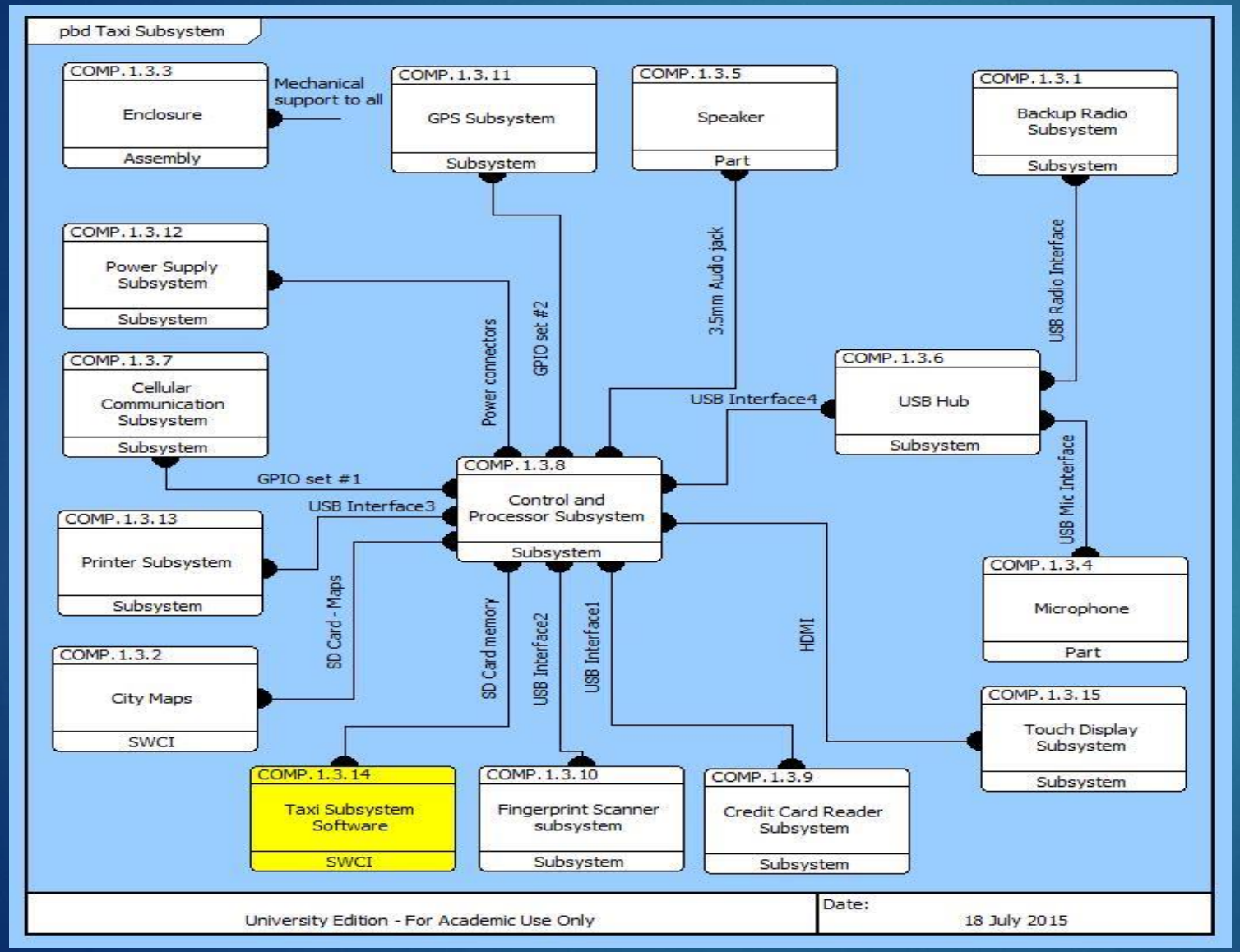
Functions

Data Flow

Taxi Booking Subsystem

- Entirely software
- Can run
  - As GUI Mobile application
  - Desktop web browser
- Provides Emergency soft-button during trip
- Runs other threads for login, history, payment options

Physical Concept – Taxi Subsystem PBD



- Taxi Subsystem
1. Control & Processor Subsystem
2. Taxi Subsystem Software
3. GPS Subsystem
4. Fingerprint scanner subsystem
5. Credit Card Reader Subsystem
6. Printer Subsystem
7. Cellular Comms Subsystem
8. Backup radio subsystem
9. Touch display subsystem
10. Microphone
11. Speaker
12. Power supply subsystem
13. USB hub
14. City maps
15. Enclosure

- Components Traced to Functions

Physical Concept – Interfaces

	Interface between Subsystems	Physical Implementation of Interface	What flows?	Functions/ Functional Interactions
1.	Control Center Subsystem and Taxi Booking Subsystem	Wireless Internet	Booking request Request Status (Accept/ Reject) Allocated Taxi info – location and ETA Trip completion info – fare Emergency Alert	FUNC.1 Accept customer request for taxi FUNC.1.2 Get request input from customer FUNC.3.3 Send allocated taxi information to customer FUNC.8.2 Enable emergency alarm generation
2.	Control Center Subsystem and Taxi Subsystems	Wireless Internet	Booking Request Request Accept/ Reject Allocation confirmation Request closure intimation Current taxi location Driver authentication status Taxi subsystem health status Trip information- start, stop, payment status Taxi status – Engaged, Available Ad-hoc communication messages with driver	FUNC.3.1.1 Send requests to nearest five Available taxis FUNC.3.1.2 Accept/ Reject request FUNC.3.2 Send confirmation to allocated taxi FUNC.3.4 Send request withdrawal to other taxis FUNC.7.2.1 Transmit taxi location periodically FUNC.8.1.3 Update authentication status
3.	Taxi Subsystem and Taxi Booking Subsystem	NA	NIL	

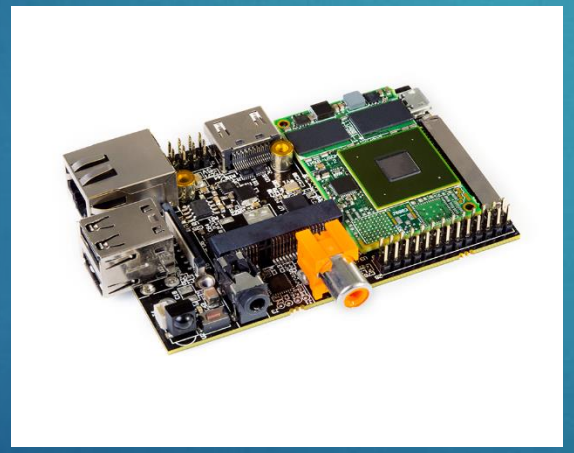
- Subsystem to subsystem interfaces are defined
  - Interfaces Mapped to Functions/ Functional interactions
- Component to component interfaces are defined for subsystems
  - Mapped to Functions/ Functional interactions

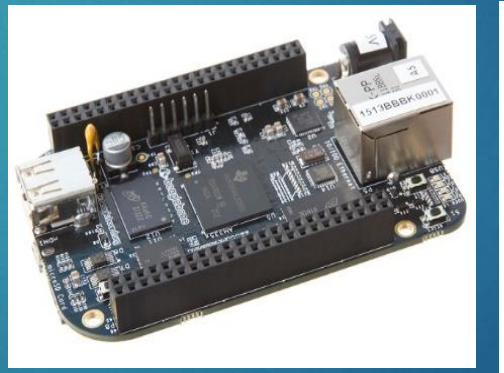
Trade Study

- Multiple informal Trade Studies done
- Formal Trade Study done to select best alternative for Taxi Subsystem's "Control & Processor Subsystem"

Four alternatives:

Raspberry Pi B+ HummingBoard i2eX BeagleBone Black Intel Galileo Gen2





Board Image reference: http://uk.rs-online.com/web/p/processor-microcontroller-development-kits/8111284/
http://www.solid-run.com/products/hummingboard/
http://www.beagleboard.org/black
http://www.intel.com/content/www/us/en/embedded/products/galileo/galileo-overview.html

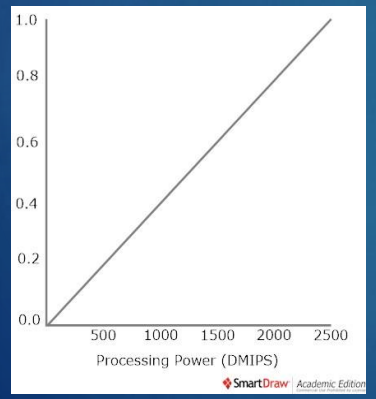
Trade Study – Selection Criteria

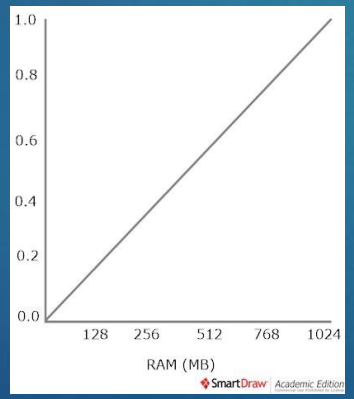
	Selection Criteria	Unit	Rationale	Requirement Reference
1	Processing power	DMIPS/ MHz	Need to implement Graphics intensive functions – navigation, best route calculation & display, in real time. Other control functions .	REQ 5.5 The taxi subsystem shall have processing power to perform graphical processing for maps display, route calculation, real time updating of route display.
2	RAM	MB	RAM determines the ability to process large amounts of data. Higher RAM is desirable to host graphics intensive application.	REQ 5.6 The taxi subsystem shall have sufficient RAM to support graphics intensive processing for navigation functions.
3	Number of USB ports	Number	Need to interface other COTS subsystems with USB interface - portable printer, credit card reader, and fingerprint scanner	REQ 5.8 The taxi subsystem's Control Subsystem shall have sufficient number of USB ports to support COTS peripherals like mini printer, credit card reader, finger print scanner.
4	Number of add-on boards available	Number	Availability of readymade add-on boards (GPS, cellular, WiFi, etc.) reduces our R&D effort and cost.	REQ 5.7 The taxi subsystem shall use as many COTS components as possible to reduce R&D time and cost
5	Power consumption	W	Need to minimize power consumption as it depends on car power system.	REQ 5.10.1 The taxi subsystem shall have a total power consumption of less than 20W
6	Number of Operating Systems supported	Number	Multiple OS support will allow future OS migration if needed, a risk mitigation strategy.	REQ 5.9 The taxi subsystem shall support more than one Operating Systems

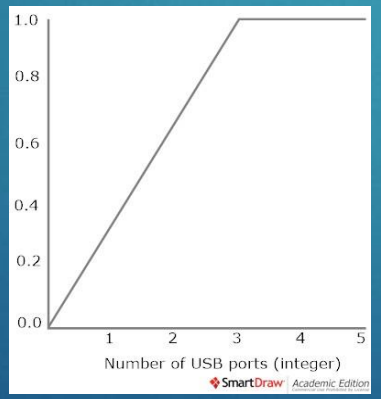
Trade Study – Weights & Utility Functions

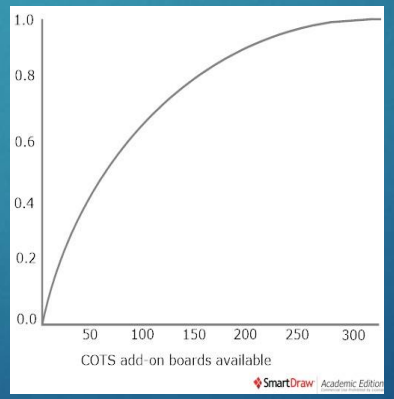
Letter Assigned	Selection Criterion
A	Processing Power
B	RAM
C	Number of USB ports
D	Number of add-on boards available
E	Power consumption
F	Number of operating systems supported

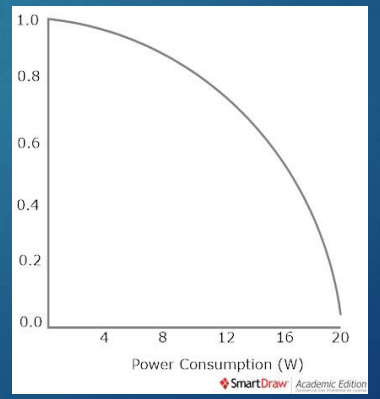
	A	B	C	D	E	F	Row value products	Nth root of row value products	**Normalized weighting factor**
A	1.00	1.00	5.00	3.00	4.00	3.00	180.000	2.376	**0.333**
B	1.00	1.00	2.00	1.00	5.00	3.00	30.000	1.763	**0.247**
C	0.20	0.50	1.00	0.33	3.00	1.00	0.100	0.681	**0.095**
D	0.33	1.00	3.00	1.00	4.00	1.00	4.000	1.260	**0.176**
E	0.25	0.20	0.33	0.25	1.00	3.00	0.013	0.482	**0.067**
F	0.33	0.33	1.00	1.00	0.33	1.00	0.037	0.577	**0.081**
									1.000

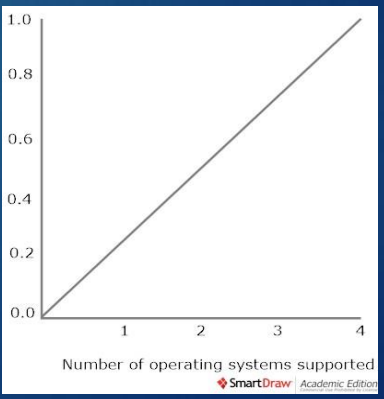












Trade Study – Final Selection

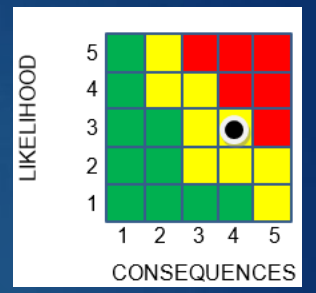
		Raspberry Pi B+		Hummingboard i2eX		Beaglebone Black		Intel Galileo Gen 2	
	Weight	Utility score	Weighted utility score	Utility score	Weighted utility score	Utility score	Weighted utility score	Utility score	Weighted utility score
Processing power	0.333	0.386	0.128	1	0.333	0.8	0.266	0.2	0.067
RAM	0.247	0.6	0.148	1	0.247	0.6	0.148	0.4	0.099
Number of USB ports	0.095	1	0.095	0.6	0.057	0.2	0.019	0.4	0.038
Number of add-on boards available	0.176	1	0.176	1	0.176	0.5	0.088	1	0.176
Power consumption	0.067	0.9	0.061	0.82	0.055	0.95	0.064	0.6	0.040
Number of operating systems supported	0.081	1	0.081	0.5	0.040	0.75	0.061	0.5	0.040
Weighted sum			0.690		0.909		0.646		0.461
Cost			25		110		55		75
Weighted sum*1000/cost			**27.605**		**8.266**		**11.754**		**6.145**

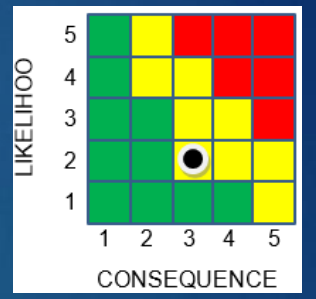
- Sensitivity analysis done
- Raspberry Pi B+ is selected based on
  - cost effectiveness and
  - additional research of lab test reports of Raspberry Pi B+ and HummingBoard i2eX on graphics performance

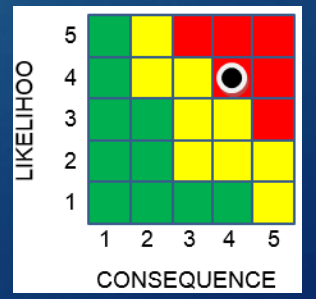
Raw scores and additional research references: https://en.wikipedia.org/wiki/List_of_ARM_microarchitectures
http://www.intel.com/content/dam/www/public/us/en/documents/training/soc-x1000-introduction-seminar.pdf
http://shieldlist.org/
http://liliputing.com/2014/04/hummingboard-raspberry-pi-compatible-dev-board-freescale-mx6-chip.html
http://beagleboard.org/cape
http://www.intel.in/content/www/in/en/embedded/products/galileo/galileo-overview.html
http://www.mouser.com/applications/open-source-hardware-galileo-pi/
http://makezine.com/magazine/how-to-choose-the-right-platform-raspberry-pi-or-beaglebone-black/

Risk Management

- Two Risks identified in Project Report and Tracked
  - Risk#1 "Unreliable Communication System"
    - IF Communication technologies used (internet via cellular network) do not provide reliable connectivity THEN Taxis will not get the required information from the Control Center about prospective customers and this will result in low availability of system. High Availability and High Reliability of the system may not be achieved.
  - Risk#2 "Accuracy and Reliability of Taxi Location Determination"
    - IF the location determined by Taxi Subsystem is not be reliable and accurate THEN - 1) The taxis may not reach the customer. 2) Customer may be provided with incorrect taxi locations. 3) The system may allocate incorrect taxis to a customer. 4) Accurate tracking of taxis for safety will not be achieved.
  - Risk#3 "Insufficient Backup Radio Range" (New risk in A-spec)
    - IF the backup radio subsystem (data modem) does not have a range of full 40 km (system coverage area) then Taxi Subsystems in 10 km to 40 km range will not be able to communicate with Control Center when there is no cellular communication coverage, and desired High Availability and Reliability may not be achieved.



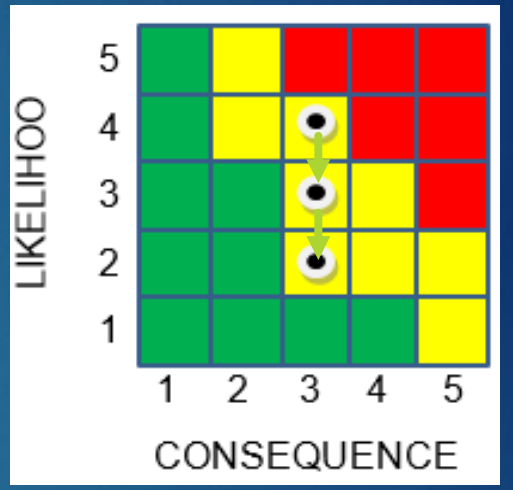




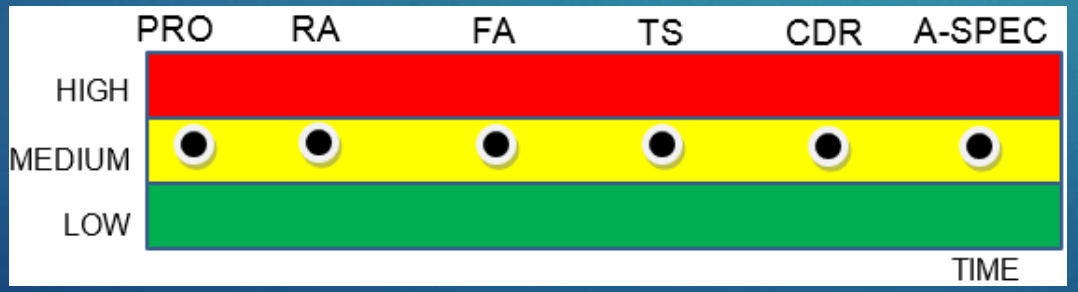
Risk Management – Risk#2 Details

- Risk#2 "Accuracy and Reliability of Taxi Location Determination"
- Initial assessment: Likelihood = 4, Consequence = 3

Mitigation Plan			L	C	Impact Description & Rationale
ID	Associated Report	Mitigation Action			
1.0	RAR	Use US GPS and Russian GLONASS global navigation satellite system receivers in Taxi Subsystem	3	3	Employing different satellite systems will increase the probability of finding the signal and accurate location determination, thus increasing the reliability and accuracy. The likelihood of risk materializing is reduced.
2.0	CDR	Use GPS Subsystem that supports GPS, GLONASS and GALILEO	2	3	Use one more positioning system to reduce likelihood of not finding the location



Risk waterfall



Risk progression through various phases

System Specification

- More requirements added – subsystem interfaces, maintenance, subsystem reliability, availability
- Growth in # of requirement from

  RAR to A-Spec = 40.96%
- Requirements Summary

	Total	Quantitative		Qualitative	
			%	Binary	Subjective
User Need Requirements	6				6
Requirement Analysis Report	83	19	22.89	57	7
Functional Analysis Report	88	19	21.59	62	7
Trade Study	93	23	24.73	63	7
Conceptual Design Report	103	33	32.03	63	7
System Specification Report	117	81	69.23	36	0

	KPP	Values	Requirement
1	Time to receive response from system for a taxi booking request	Objective: 60 sec Threshold: 150 sec	REQ.2.1.2.3 The system shall provide "Taxi On The Way"/ "Taxi Not Available" response to customer in no more than 60 sec (O), 150 sec (T), after customer sends the booking request
2	Taxi driver identity check period	Objective: Every 30 min	REQ.3.1 The system shall ensure positive taxi driver identification every 30 min to prevent any crimes.
3	Emergency alert time	Objective: 30 sec Threshold: 60 sec	REQ.3.4 The system shall enable enhanced passenger safety by informing police station or emergency teams in no more than 30 sec (O), 60 sec (T) after the travelling customer raises an emergency alarm
4	User handling capacity	Objective: 5000 Threshold: 4000	REQ.4.2 The Control Center Web Servers shall handle no less than 5000 (O), 4000(T) simultaneous customer user connections
5	Payment options	Objective: 4 options Threshold: 3 options	REQ.5.15.2 The system shall provide no less than 4 (O), 3(T) payment options out of 1) credit card, 2) debit card, 3) prepaid card, 4) online wallet, 5) cash
6	System Availability	Objective: 98%	REQ.6.4 The system shall achieve an availability of 98% over a period of 1 year of continuous operation

Summary of Final Concept & Future Work

- Three subsystems- Control Center (one), Taxi Booking Application (many), Taxi Subsystems (many), Communicate over Wireless Internet, provide taxi tracking, emergency soft-button.
- Future work
  - Backup radio range improvement/ alternate solution
  - Police/ emergency team interface detailed definition
  - Unique Identity Server (AADHAR) interface detailed definition
  - Commercialization/ productization of Raspberry Pi/ add-on boards
  - Control Center facility layout and support systems

Lessons Learned

- Two-way Traceability must be done for Requirement <-> Functions and Functions <-> Components for completeness and no gaps
- Do not commit to a performance requirement without adequate research and feasibility analysis
- Need to Communicate with a multitude of people (customers, users, SMEs) to mine requirements. Continue communicating to refine and add new requirements.
- MBSE tool like Core helps maintain consistency throughout systems engineering, which will otherwise be very tedious and difficult to do

Recommendations

- Vitech Core or any other MBSE tool use can be more emphasized in other courses so that it becomes easy to use for Project work
- The Project Guidelines document should be made available in Conceptual Design & Integration Course so that everybody is well aware about the project timeline and expected start time.

Thank you