Systems Engineering Midterm Questions

1. (5%) For four of the “simple” systems listed in the following table, identify the object elements or abstractions of form that you will represent.
2. Identify the system, its form and its function (Section 2.3).

System: Model balsa glider with propeller

Form: The Glider

Function: Traverses

System: A prosecutor in a court of law

Form: The prosecutor

Function: Argues

System: A basic fiberglass canoe

Form: The canoe

Function: Navigates

System: Simple gender-neutral office exam with physician

Form: The exam

Function: Determines

1. Identify the entities of the system, their form and function, and the system boundaries and context (Section 2.4).

System Function: Traverses air

Entity Function: Achieves lift, slows drag, balances weight

Entity Form: Propeller, Wings, Fuselage

System Form: Glider

System Boundaries: The boundary of the glider extends to only the design of the glider. The system boundary would not include a device or human initially propelling the glider or keeping it in the air. The glider’s performance is being analyzed and the only factor’s to be improved in the design directly involve the glider’s components.

Context: The context of the glider includes how the airplane interacts with aerodynamics and the wind. The mechanisms or human used to propel the glider would not be inside the system boundary and therefore would be part of the context because it affects how the glider will fly but is not part of the scope of the design of the actual glider.

System Function: Argues law

Entity Function: provides environment, disputes prosecutor, decides case, intermediates trial

Entity Form: courtroom, defendant, jury, judge

System Form: Prosecutor

System Boundaries: The system’s boundaries include only the interacting bodies in the courtroom, the relevant consultation material for the trial, evidence relevant to the particular trial, witnesses testifying only in this particular trial, and jury members presiding over the trial.

Context: The system’s context could include evidence not presented at trial or dismissed at trial, witnesses that refrain from testifying, witness testament outside of the courtroom that differs from inside of the courtroom, judge’s comments on the trial off-the-record, additional co-prosecutor’s arguments, and jury members excluded from the trial during the selection phase.

System Function: Navigates water

Entity Function: guide canoe, provides storage, seat users

Entity Form: Paddles, floor, seating platforms

System Form: Canoe

System Boundaries: The system boundary would include paddles and life-jackets even though they’re not strictly part of the canoe because almost every canoe system utilizes both. The paddles’ design would be in tandem with the canoe’s to add to the canoe’s performance and efficiency. The weight of the life jackets would be taken into account as a safety regulation but whether a user wore them would not be considered. The ideal weight limits of canoers would be taken into consideration but not the way the canoers interact with the canoe when they’re using them. The ability of the system to support modifications to the base canoe would be taken into consideration but any added modifications not part of the base canoe would not be relevant to its base performance.

Context: The navigable water bodies the canoe could be used on and how they interact with the canoe would not strictly be part of the system. The way the canoer uses the canoe would not be part of the system’s design even though they affect the performance of the canoe. External weather events would not be a part of the system neither but could still affect its ability to navigate waters. Any live animals interacting with the canoe, such as a fish jumping into the boat or a crocodile taking a bite out of it, may affect the weight/performance but would not be part of the system boundary.

System Function: Determines health

Entity Function: guide assessments, gauges health, administers tests

Entity Form: procedures, readings, physician

System Form: Physical Exam

System Boundaries: Only the tests listed out in the narratives, only the instruments used to conduct the tests and the numerical/qualitative measurements they give, only the opinion of the particular physician from the narrative, and only the exam as it relates to the individual taking the physical.

Context: Tests conducted outside of this particular physical exam would not be part of the system boundary, past physical exams leading to a more well-rounded health assessment would not be part of this particular exam, and alternate physician determinations based on the same readings from the same physical exam.

System Boundaries:

1. Identify the relationships among the entities in the system and at the boundaries, including their form and function (Section 2.5).

See Excel file for detailed answer to this problem

1. Based on the function of the entities, and on their functional interactions, identify the emergent properties of the system (Section 2.6).

Glider: Achieves aerodynamic lift and steady flight for a period of time. Failure to satisfy the system’s emergence would result in the balsa glider quickly falling to the ground.

Prosecutor: Achieves a proper sentencing for a defendant in the court of law, based on the law, evidence, and witnesses. Emergence will not necessarily result in a verdict of guilty for the defendant but will be up to the determination of the jury/judge to reason through. The prosecutor’s emergence in relation to a court of law is to convince the jury/judge of the defendant’s guilt. The prosecutor would like for a guilty verdict because if the case is being prosecuted, the prosecutor has deemed it worthwhile to convince the jury/judge of the defendant’s guilt. Unanticipated emergence would be corruption leading to a wrong verdict such as witness tampering, evidence destruction, etc…

Canoe: Achieves the transportation of canoers and/or equipment across bodies of water. The fiberglass structure of the canoe leads to a durable structure sufficient to withstand the forces of the bodies of water it will traverse and to a supportable structure up to a certain amount of weight. Unanticipated emergence would consist of the boat capsizing, sinking, not being able to create momentum for movement in water, and not being able to control the direction of movement in water.

Physical Exam: Achieves the result of accurately transmitting correct information to the patient coming in for a exam. Within the system boundary, this does not mean that the exam solves the patient’s medical issues but it makes the patient aware of any pending medical issues he/she may have so the patient can take further action. Unanticipated emergence would consist of the patient receiving inaccurate results, misdiagnosing conditions the patient may have, not having the proper equipment to test for all of the measurements standard in a physical exam, the exam not being properly administered to ensure validity of results.

1. (5%) A DSM of the TCP/IP suite is shown on the next page, read across the rows to the column. For example, an entry at [2,5] would indicate a connection from 2 to 5.

Create a network representation of this layered hierarchy, showing the connections between elements, as well as which layer the elements are located in.

Above problem is from Chapter 3

The network representation of this layered hierarchy can be seen in the attached PowerPoint.

The fundamental layers of the network representation are the TCP/IP Suite, Application, Presentation, Session, Transport, Network, Data Link, and Physical. The listings below each layer are members in that layer. Items to the left outside of the dashed box are outside of this particular system’s boundary.

Connections Present (total: 42)

1. [3,7] – Trailers to IP – Data Link to Network
2. [7,2] – IP to L2F, PPTP, L2TP, ATMP – Network to Data Link
3. [7,8] – IP to ICMP – Network to Network
4. [7,9] – IP to RSVP – Network to Network
5. [7,10] – IP to VRRP – Network to Network
6. [7,11] – IP to IMGP – Network to Network
7. [7,13] – IP to TDP, MPLS – Network to Network
8. [7,16] – IP to ESP, AH – Network to Network
9. [7,17] – IP to BGP, RIP, GRE – Network to Network
10. [11,12] – IMGP to PIM – Network to Network
11. [7,22] – IP to TCP – Network to Transport
12. [7,25] – IP to UDP – Network to Transport
13. [22,6] – TCP to CSLIP SLIP – Transport to Data Link
14. [25,14] – UDP to DHCP – Transport to Network
15. [25,15] – UDP to BOOTP – Transport to Network
16. [25,24] – UDP to RUDP – Transport to Network
17. [20,18] – XOT to X.25 – Transport to Transport
18. [21,19] – ISO DE to ISO TP – Transport to Transport
19. [22,20] – TCP to XOT – Transport to Transport
20. [22,21] – TCP to ISO DE – Transport to Transport
21. [25,26] – UDP to Mobile IP – Transport to Transport
22. [22,23] – TCP to TALI – Transport to Transport
23. [25,33] – UDP to DSMCC (MPEG) – Transport to Session
24. [23,32] – TALI to SS7 – Transport to Session
25. [22,31] – TCP to LDAP – Transport to Session
26. [22,30] – TCP to DNS – Transport to Session
27. [22,29] – TCP to Net-BIOS-SN – Transport to Session
28. [22,28] – TCP to Net-Bios-SSN – Transport to Session
29. [25,47] – UDP to RTSP – Transport to Application
30. [25,45] – UDP to HTTP-S, SSH, RADIUSM ISAKMP – Transport to Application
31. [25,44] – UDP to TFTP NTP – Transport to Application
32. [25,41] – UDP to RLOGIN, RSHELL, PRINT, REXEC, RWHO – Transport to Application
33. [25,34] – UDP to IMAP4 – Transport to Application
34. [22,40] – TCP to TACACS+,TACACS – Transport to Application
35. [22,39] – TCP to CMOT, SNMP – Transport to Application
36. [22,38] – TCP to COPS – Transport to Application
37. [22,37] – TCP to SCTP – Transport to Application
38. [22,36] – TCP to FTP, Telnet, SMTP, POP3, HTP – Transport to Application
39. [46,40] – WCCP to TACACS+,TACACS – Application to Application
40. [45,39] – HTTP-S, SSH, RADIUSM ISAKMP to CMOT, SNMP – Application to Application
41. [40,46] – TACACS+,TACACS to WCCP – Application to Application
42. [39,43] – CMOT, SNMP to SLP – Application to Application

Glider (Standard class glider (15-m span))and Judicial Systems (U.S. court criminal court. See the following description) (Chapter 6)

1. (10%) For each of the two systems, what are the key value-related internal processes? Develop a model of the key internal value-related processes and the flow of value through the intermediate operands. Represent this with an instrument-centric and a process-centric view of the “flow” along the primary value path. Again, use either a matrix (DSM or other) or graphical (OPM or other) representation. Identify objects of form whose function is not yet identified: interfaces, other value processes, or supporting processes.

Forms not yet identified for glider system: wing span changes lift and drag, user chooses launch height, user chooses launch location, user chooses launch time, user chooses launch weather, design determines balsa thickness, design determines glider weight, design determines retro-fits, wing shape determines flight characteristics, and fuselage length changes center of gravity.

Forms not yet identified for Judicial System: judge instructs jury, judge interprets applicable law, defendant’s attorney debates prosecutor, prosecutor adjusts argument, defendant’s attorney adjusts argument, jury modifies opinion, officers secure defendant, defendant testifies, judge or jury decides trial (not both), prosecutor settles with defendant

See PowerPoint for the key value-related internal processes of the glider system and Judicial System.

1. (10%) Identify the important steps in operation (behavior/dynamics) of the product system, versus the static functions for both systems. For one of the two systems, develop a representation of the behavior of the system, such as the line operations diagram for the corkscrew. Was the dynamic behavior of the system important to represent?

A number of processes must be taken into account for a dynamic glider system. To actually launch the glider, a human or launching mechanism must be used. The human/launching mechanism must be brought to the test site for the glider and a launching mechanism must be properly configured to support the glider’s launch. If a human is to launch the glider, his/her arm must be capable of an extension/retraction to physically throw the glider or accelerate it forward using some other type of method. The propeller, the main driving force behind initial flight and lift, remains stationary in the back of the glider and potentially wings too up until launch. As soon as launch takes place, the propeller and its comprising blades, if working correctly, should start working rotating about a 360 degree axis. The actual propeller as part of its mission operations, will be brought from a storage area free from potential damage and heavy moisture that could deteriorate the balsa. After flight, the glider needs to be carefully inspected for damage each time. Considering the glider is made out of balsa and will not have reinforced thick supports, it is prone to damage. The slightest chips in the balsa could significantly decrease the performance of the glider. The glider’s parts can be repaired depending on the damage but would most likely need to be replaced adding another process to the system.

Many processes take place in a dynamic Judicial System with a prosecutor. When the system’s operand is the prosecutor, the function of the system will be to focus on his arguments. The Judicial System as a whole encompasses many acting pats both within the scope of the actual trial as well as events preparing for the trial and the aftermath of the trial. Preparation for the trial involves police work, the defendant accepting a public defender for representation or acquiring a private lawyer, collecting evidence, taking witness testimony, cross-referencing the witnesses, potential settlement negotiations, etc… Directly before a trial, the police will escort the defendant into the courtroom. The judge explains the trial in more detail, the prosecutor prepares his argument, the jury assesses non-verbal queues pointing towards acquittal or a guilty verdict, the defendant prepares his emotional state to present for trial, the defendant’s attorney prepares the defendant to answer questions that may be asked of him/her, the defendant’s attorney peruses the evidence, the defendant’s attorney searches for the most beneficial questions to ask the witnesses, those involved with the case may choose to preside as a watching party towards the back of the courtroom, and the jury will avoid talking about the case unless instructed by the Judge. During trial, each side will present their case, the judge will moderate the process and step in when necessary, the jury will intently listen to both arguments and independently form their opinions, witnesses will be called to the stand, witnesses will testify under oath, evidence will be examined, each side will give opening and closing arguments, and finally a verdict will be reached. One tricky aspect of the dynamic Judicial System is the time length may vary extraordinarily for trials from days to years. After the trial, the defendant may be free to leave or will be escorted by officers to prison, the prosecutor will fill out necessary paperwork, the case may be appealed and the judge will need to provide information to other courts regarding the case, and the jury members will be forbidden from talking about the trial.

The glider’s dynamic representation was useful to represent because it provides context behind the design of the actual system. The actual system, consisting only of the glider’s design, may work theoretically in a static environment but would not work in a dynamic environment or be effective. For example, the system’s design may make an extremely aerodynamic glider by thinning the balsa wood but when examined dynamically, it could be shown that after its first test the balsa would most likely need to be repaired significantly. All the dynamic processes need to be accounted for to make the system’s design the most practical. A dynamic context forces the system’s architect to think about the way external processes affect the system ahead of time so as to avoid unforeseen difficulties.

1. (10%) Represent the system from Problem 4 using the appropriate SysML diagrams.

See PowerPoint and Excel Table for the appropriate SysML diagrams.

1. (10%) For each of the two systems, what are the key supporting processes and instruments at Level 2? Develop a layered representation of the functional architecture. Did the inclusion of supporting processes and instruments reveal new external interfaces?

See Excel Tables for the appropriate key supporting processes and instruments at Level Two. The layers can be seen as the defining processes and operands/form.

The inclusion of supporting processes and instruments did reveal new external interfaces. At level 2, a well-rounded understanding of the system’s environment begins to take place. The small details are defined to show what exactly the system contributes. At level 2, the interactions between the different process and operands/forms is no longer ambiguous. A level 2 is oftentimes sufficient to understanding a system because the level of detail at this level can usually cover the scope of the system. The downflow of processes to level 2 helps reshape and obviate any flaws in the Level 1 processes for further refinement. The operands and form interacting with the processes at Level 2 show the trickle effect of what the system actually affects and how to modify the system to give more of the desired effects.

1. (10%) For the system that you are working this semester in your project tasks, produce a hierarchy of solution-neutral statements with multiple potential specializations at each level.

See PowerPoint for the appropriate hierarchy of solution-neutral statements with multiple specializations at each level.

1. (20%) Suggest a Level 1 modularization for glider and judicial systems you used in questions 3, 4, 5, and 6? How was it informed by the formal structure, operand interactions, and internal function(s)?

See Excel Tables for a Level 1 modularization for each system.

The formal structure, operand interactions, and internal function(s) help to functionally group the processes rather than by a timeline of events. By clustering the processes, a pattern develops. The clusterings show where the processes will share similarities to their operands at the highest level. The application of modularization is effective for both the glider and Judicial System because they’re not heavily reliant on time for defining the system’s performance. Time is a variable but the modularization for each shows the similarities that attribute the most to the processes at Level 1.

1. (20%) Identify all the value pathways of the functional architecture developed for question 5. Provide a quantitative and/or qualitative model based on value pathways that can assess the functional architecture with a numerical value.

A quantitative model based on the value pathways of a glider would be relatively simple. The ultimate simplified measurement to determine the effectiveness of a simple glider would be the lift/drag ratio, as exemplified in the value pathways. The forward distance traveled in the air until hitting the ground in combination with flight time could be another measurement to determine the effectiveness. Both are commonly used values to measure the effectiveness of aircraft. The formula to calculate the lift/drag ratio would need to depend on many simplified assumptions since it is only a balsa glider but a scaled formula would show how each balsa glider compared to others. I’m not sure if this question was directly asking for the model or how a model could be deduced from the architecture but I’ve provided sample pseudocode that could be ran in MATLAB or any language below:

A = input; %aspect ratio (dimensionless based on glider’s measurements)

Sigma = input; %span efficiency factor, consult tables to get value

N = 3.1415926; %Pi

CDnot = input; %zero-lift drag coefficient (dimensionless), consult tables to get rough assumed value

Lift\_over\_Drag = 0.5\*((N\*A\*Sigma)/CDnot)^0.5; %Lift/Drag ratio

The above equation numerically describes how the aircraft should fly in theory, however, miscalculations, assumptions, imperfections, may show the design actually doesn’t perform how it would be expected to. A practical equation based off of tests would then be the forward distance traveled until hitting the ground multiplied by the time it traveled to give a ft-s measurement. Although dividing by the time it traveled would give a standard velocity measurement, with balsa gliders, one of its main performances is to achieve steady level flight by moving forward. The longer the balsa is able to stay in the air while moving forward, the better its desired performance.

Qualitatively, it should be obvious which glider is best during testing by observation. Some designs for balsa may look aerodynamic because of their similar appearance to an actual plane but the flight characteristics will be different at a balsa glider scale. It would also be very easy to mash up a pile of balsa wood into a ball, claim it is a glider, and throw it but this takes away from the purpose of the exercise. Depending on the architecture it may be acceptable to qualify this as a glider but if the intended design of the balsa glider is to mimick actual aircraft, a design like this wouldn’t work. Many derivatives of a balsa glider could be eliminated from competition based off of this.

Relating back to the architecture, a model that takes into account Lift/Drag Ratio and Propeller Power should be sufficient for describing the balsa glider’s performance. A higher Lift/Drag Ratio and Propeller Power should lead to better performance, assuming steady flight.

For a Judicial System, a qualitative model works better for describing the effectiveness of the architecture. While many measurements can be taken into account with balsa glider testing, there are few numerically relevant results in a trial other than the outcome, which could be a binary result as 1 as a guilty and 0 as an acquittal. The best numerical system could consist of the number of jury votes swaying one way or the other. For example, more votes either acquitting or returning a guilty verdict would indicate that everything presented during trial made the conclusion evident to the jury. Not all cases are decided by a jury, however, so additional methods would be needed. In cases decided by judges, it would be imperative to take into account a number of variables such as decided sentence length, number of times the offense has occurred, severity of the crime, past related felonies, etc… Subjectivity is allowed on the end of judges so developing a numerical system would be extremely difficult, a qualitative system makes more sense. The pseudocode for the most effective jury-decided Judicial System would be as follows:

J = input; %number of jury members presiding at the trial

Y = input; %jury members voting for guilty verdict

A = input; %jury members voting for acquittal

If Y > (0.75\*J)

Y = Y/J

Elseif A > (0.75\*J)

A = A/J

End

The system above quantifies the jury deciding a trial to be effective if 75% of the jury either vote for acquittal or a guilty verdict. If the 75% threshold is met, the percentage voting for acquittal or a guilty verdict will be returned.

For judge-decided cases, a formula could be as follows:

Number\_of\_Relevant\_Case\_Laws\_Voting\_Acquittal = input;

Number\_of\_Relevant\_Case\_laws\_Voting\_Guilty = input;

Verdict = input; %1 for guilty, 0 for acquittal

Acquittal\_Percentage = Number\_of\_Relevant\_Case\_Laws\_Voting\_Acquittal/(Number\_of\_Relevant\_Case\_Laws\_Voting\_Acquittal+Number\_of\_Relevant\_Case\_Laws\_Voting\_Guilty)\*100;

Guilty\_Percentage = Number\_of\_Relevant\_Case\_Laws\_Voting\_Guilty/(Number\_of\_Relevant\_Case\_Laws\_Voting\_Acquittal+Number\_of\_Relevant\_Case\_Laws\_Voting\_Guilty)\*100;

If Acquittal\_Percentage > 50

Verdict = 0

Elseif Guilty\_Percentage > 50

Verdict = 1

The pseudocode above describes how if past relevant cases resulted in either acquittal or guilty more than 50%, the case at trial would be effective if it returned a verdict favoring past decisions. This formula could provide a general solution, although there would be plenty of shortcomings. The formula above could lead to bias at trials where past relevant case law sways strongly one way or the other. Also, there would need to be clear cut definitions about what qualifies as a relevant case. If enough cases utilize the formula, the numerical results should balance to show trends where returning a guilty or acquittal verdict would match past results.