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DRAGONFLY:

Developing a proposal for an Uninhabited Aerial Vehicle (UAV)

This case was written by Stylianos Kavadias, Ph.D. candidate of Operations Management at INSEAD, under the supervision of Christoph Loch, Associate Professor of Operations Management, and Arnoud De Meyer, Professor of Operations Management. It is intended to be used as a basis for class discussion, rather than to illustrate either effective or ineffective handling of an administrative situation. All names of individuals and companies are fictitious.

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Introduction

"… so we should be able to do it, Bob!" Sam Morris concluded his short presentation in this early morning meeting. The tall chief technical officer (CTO) of Intelligent Aircraft Co. (IACo) looked confident. The CTO reiterated that IACo needed to win the bid in the next European Union (EU) auction for aerospace operational programs, in order to pay for the R&D expenses already invested and to replace their aging helicopter that was approaching the end of its life. "Today is Wednesday, May 1. Remember, we must make the deadline ten weeks from Monday, otherwise we have no hope. Aerospace Associates Inc. will get it!"

"OK, Sam, I'm in," said Bob Lake, development manager for special projects. "I'll start collecting information right away." He walked out of the presentation, mumbling some disrespectful remark about Brussels bureaucrats and their procedures. In his head, he was already counting things to be done, time and resource requirements. He wondered whether they could meet a deadline as ambitious as this. In the past, IACo had had trouble getting projects done on time.

UAV

The unmanned aerial vehicle (UAV) was a new trend in the aerospace industry since the mid 1990s. The Association of UAV had summarized the major purposes for such a development as follows:

UAV technology can potentially be used in many aerial applications, such as:

- aerial surveys for agriculture, traffic monitoring and pollution control

- meteorological data collection

- inexpensive and efficient experimental research platform for flight control systems

- autonomous target detection, identification, classification and interception

- real-time command and control for a variety of combat situations

- reconnaissance missions for gathering information

- law enforcement purposes

Source: http://www.erols.com/auvsicc/uav.htm

IACo's R&D group had developed an unmanned helicopter prototype, the DragonX1 (Exhibit 1), which offered unprecedented compactness and low weight. The bid by the EU Commission would make mass production possible. Thus, the immediate concern was to develop a competitive proposal "Dragonfly" within two months to win the order (or at least a large part of it).

Project Development

In order to schedule the Dragonfly project, Bob Lake had to contact the engineers who had developed the prototype and extract as much information as possible from them. So he visited

Peter Van Zandt, the engineer responsible for the DragonX1, in South London. He did not know him, but Bob's contacts in the engineering department described Peter as a silent, effective senior engineer.

Peter willingly started to describe the development phases of the DragonX1. He soon got into the structural finite-element analyses, internal load distributions and dynamic feedback control issues associated with the prototype, until Bob interrupted him: "Sorry Peter, I was not actually planning to go into all the details, yet. Could we go through the additional work required to make a detailed proposal for a commercial development? Only at the summary level?" After four hours of work, the two produced a high-level list of the activities required for the bid proposal (Table 1).

Table 1. Activities of Dragonfly project

Activities	Description	Expected Duration (days)
A1	*Prepare preliminary functional and operability requirements and create preliminary design configuration*	9
A2	*Prepare and distribute surface models*	3
A3	*Perform aerodynamics analysis and evaluation*	11
A4	*Create initial structural geometry and prepare structural geometry and notes for finite-element structural simulation*	7
A5	*Develop structural design conditions*	8
A6	*Perform weights and inertia analyses*	6
A7	*Perform structure and compatibility analyses and evaluation*	21
A8	*Develop balanced freebody diagrams and external applied loads*	10
A9	*Establish internal load distributions, evaluate structural strength stiffness and life and preliminary manufacturing planning and analysis*	15
A10	*Prepare UAV proposal*	5

The list was, however, only the first step. It contained no sequence, no logical "flow" of the order in which the activities had to be done. Bob and Peter could not produce an activity "flow" on their own; it had to be done with the engineers who knew how the different activities interacted. As this project had a very high priority (pushed by Sam Morris himself), Peter promised to circulate the list of activities within the engineering group and get Bob a sequence by tomorrow.

The next day, Bob had another document in hand. It was a standard type of representation (Table 2) among engineers. "This is what we call Design Structure Matrix (DSM)," said

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Peter. The DSM was an easy to understand, graphical way of representing interdependencies among activities. Each row indicated the *dependent activities* and each column the *input providing activities*. Dependent activities required input in the form of results from the input-providing activities. An example in Table 2 is activity A5, which depended on the outcome of activities A1 and A4.

Table 2. Design Structure Matrix

Dependent Activity	Input Providing Activity									
	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	■									
A2	|	■								
A3	|	|	■							
A4	|			■					|	
A5	|			|	■					
A6				|		■				
A7	|		|			|	■			
A8			|		|			■		
A9				|				|	■	
A10	|	|	|		|	|	|	|	|	■

"What about this strange dependence of activity A4 on activity A9?" Peter explained that there are cases in which the interdependence among activities is mutual. He and his colleagues had encountered similar phenomena in past projects and finally had to iterate several times among these activities. In the specific case of structural geometry and manufacturing planning, experience showed that the engineers had to go back to activity A4 approximately 30% of the time, due to incompatibility reasons (i.e. the initial geometry was not appropriate for manufacturability purposes). Bob Lake was beginning to get a picture of the project activities. Based on the completion time estimates in Table 1, he could start estimating the completion time of the project.

Bob was aware that time estimates were, of course, never correct. He decided to challenge the engineers. He called Peter Van Zandt. "Tell me Peter, how accurate are your time estimates?" "Well, not very, they are only wild guesses," Peter replied without hesitation. "This project is crucial," said Bob. "We need a risk estimate of running over schedule, which would cost us the job." Peter promised to see what he could do about it.

In the afternoon, Bob received a fax with another table of estimates. "Here we are, Bob." The design team had "unofficially" calculated the uncertainty of each activity. The estimates were based on their experiences from past projects and from their judgment about how difficult the activities in this project would be. Table 3 shows, for each activity, an estimate of the "best case value" (BCV) and "worst case value" (WCV), complementing the "most likely" values in Table 1.

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Table 3. Best and worst case time estimates per activity

Activities	BCV (days)	WCV (days)
A1	6	12
A2	2	5
A3	9	15
A4	6	9
A5	6	10
A6	4	9
A7	18	27
A8	8	12
A9	12	19
A10	4	6

The last major piece of information Bob needed was cost data. It would allow him to prepare a project budget. He wanted an estimate that would as closely as possible reflect real project expenses. He discussed cost estimates with Peter. "I can't give you a point value for the cost of an activity. For the commercial proposal, most of the costs are man hours. Therefore, whenever the completion time deviates from the plan, the cost deviates." Bob pondered this. "OK. I understand – just like we have a schedule *range*, we need a budget *range*. You've got figures for the daily cost of the work for the commercial proposal? Then we get a cost estimate by applying the activity duration ranges." Peter agreed – it made sense. He promised Bob to send him a fax with the estimates.

The next morning, May 3, Bob arrived early in the office. There was a two-page fax on his desk. It was from Peter, with a short note: "Hope this is useful. Have a nice day. Peter." The first page contained a cost estimation table (Table 4).

Table 4. Cost estimates per activity

Activity	Estimated Cost (€1000)
A1	15
A2	3
A3	8
A4	140
A5	12
A6	10
A7	22
A8	23
A9	90
A10	22

Below the table, Peter had written by hand: "The best proxy we could get was €2000 for each extra day of delay, per activity. Attention: *Earlier* completion will not save much. We must pre-commit resources to each activity, which we do based on the expected duration. Earlier completion doesn't save costs because we usually can't redirect a specialized engineer on such a short notice." "Wait a minute," thought Bob, "we have to pay more if we are slower than the plan, but we don't save money if we are ahead of plan? We'll have to talk about that again."

Table 5. Scenarios for time improvement

Scenario	Activity Involved	Time improvement (days)	Cost increase (€1000)
S1	A4	2	20
S2	A5	2	18
S3	A7	5	16

The fax contained a second page. "If the time estimates are not fast enough, there are a few activities where we can speed up a bit. Speeding up will require a bit more spending on materials and overtime; here are some estimates." There were three different scenarios for improvement (Table 5). "These scenarios are useful," Bob thought, "but does it really pay off to implement these changes? Will we finish earlier?"

It was almost 21:00. Bob slowly and thoughtfully sipped his second coffee. In a few hours, he needed to inform Sam of the project status. He'd better be able to answer two questions to keep his boss happy.

Question 1: How could Bob Lake formally represent the evolution of the project, showing interdependence and parallelism among activities? What was the expected completion time of the project? Assume first that the interdependence among activities A4 and A9 does not exist. Then consider how the interdependence changes the answer.

Question 2: Should any activities be shortened to ensure timely completion of the proposal, and if so, which ones? How does uncertainty in the task completion times affect project completion and the shortening of task times? What is the expected cost of the proposal and what are the ranges?

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Exhibit 1
IACo's DragonX1 in Autonomous Flight

Autonomous helicopters are a promising area for military and commercial applications, due to their advanced capabilities and great flexibility. Besides having the ability to hover, which allows one to operate in areas inaccessible to other vehicles, an unmanned autonomous helicopter can perform tasks that would be exceedingly difficult or hazardous for a manned vehicle. Possible applications for this technology include close-up inspection of power lines, terrain surveying, search-and-rescue missions, filming movies and the investigation and clean up of hazardous waste sites.

IACo's R&D group had developed a prototype, the DragonX1, to demonstrate the practicality of using inexpensive robot helicopters. The DragonX1 was a small autonomous helicopter, consisting of a heavily modified remote control model helicopter with a 30 ccm engine. Navigational sensing was provided entirely by a pair of Trimble Global Positioning System receivers operating using Differential Carrier Phase calculations. By using four separate antennas, the Dragon X1 was able to sense its attitude as well as position with GPS. As an additional sensor, it had an onboard camera system to gather additional information about its environment. Using this system, the DragonX1 was capable of object location, identification and retrieval using a retractable tether with a magnet IC manipulator.

The DragonX1's current flight capabilities included autonomous take-off, hover, trajectory following and landing. The ability to fly autonomously and retrieve a small ferromagnetic had been sufficient to attract the attention of the European Commission's Advanced Reconnaissance program, which had put out a bid for a development program to be commercialized in the energy and environmental industries.