DESIGNING TO AIRCRAFT SYSTEM EFFECTIVENESS /COST /TIME WITH VERT — THE SYSTEM ANALYSIS METHOD FOR AIRCRAFT

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ABSTRACT

This paper presents a kind of the R&D Management Decision Analysis System for Aircraft Design which based on the ideas of design-to-Effectiveness / Cost / Time and VERT (stochastic network analysis techniques), This system can provide the means with friendly ineractive interface which make the decision maker conducting the design to system effectiveness / cost / time under uncertainty perfectly and also carring out the analysis, monitoring, and controlling of the engineering design.

I. INTRODUCTION

Dereasing the costs and time of aircraft R&D and meanwhile enhancing the system effectiveness are most important targets of aircraft design. The aircraft designer must make key decisions over the life cycle of aircraft. These decisions are largely represented by three key, interrelated parametric groupings: system effectiveness (performance), cost, time. The major information needs for aircraft R&D Management of each of these three parameters in each of the life - cycle phases. At the beginning '70s, American Department of Defence (DOD) presents the concept of design-to-cost in DOD Directive 5000.28. Design-to-cost is a process utilizing unit cost goals as thresholds for manager and as design parameters for engineer. The basic ideas of design-to-cost are given as following:

1. The system's life cycle cost (LCC) should be considered. The LCC concept was first utilized by USAF (United States Air Force). The LCC is defined as that the total cost of an item of system over its full life. It includes the cost of research and development, production / acquisition, operation and support and, where applicable, disposal.

2. The key cost-driver phases of LCC are system concept design and development. During these early phases, aircraft expenditures are only 1-4 percent of LCC, but over 70 percent of system LCC are commited in these early phases.

3. In process of system design, the LCC must be treated as important design parameter as same as other performance parameters.

Since 1972, the VERT (VERT-1, VERT-2, VERT-3, VERT-4) were developed for military applications, project management, weapon system development (tanks, helicopters and fighter plans), etc. VERT (The Venture Evaluation and Review Technique) — a stochastic networking technique, is a computerized, mathematical simulation based network technique designed to analyse risk existing in three parameters in project and system — time, cost and performance (system effectiveness). It has been helpful to make decisions with incomplete or inadequate information over the process of aircraft. As design process of aircraft is a complex broad scale system engineering under uncertainty, there must be needed a kind of auxiliary analysis tool, that is so called VERT Simulation Analysis System. This is a computerize decision and simulation system which aid designer to take analysis and decision. This system can provide a means for ascertaining whether the design of system is such that it can produced within the preestablished effectiveness / cost / time target and, if not, to give warning of this in time to permit corrective action.

II. THE VERT SIMULATION ANALYSIS SYSTEM FOR AIRCRAFT DESIGN (VSASAD)

In order to take the system effectiveness / cost / time as design parameter in complex process ofsystem design , there should be an auxiliary system which can promptly carry on analysis, monitoring, controling and decision. This system can be constructed based on the ideas of design-to-cost and VERT technique.

Design-to-cost is actually an R&D management concept. The design-to-effectiveness / cost / time process is begins in concept phase and continues through production phase, operation and support phase, and then disposal phase. The concept of design -to-effectiveness / cost / time process is as following.

1. During the whole design process of aircraft, it should carry on effectiveness, cost, time programming, forcasting and tracking. Before system design, it should forcast the system amount while determining system technical performance. During determining system design alternatives, it should conduct system effectiveness / cost / time analysis and so that the analysis result will be regard as

decision criterion. After determining alternatives, effectiveness / cost / time should be assigned to subsystems according to Work Breakdown Structure (WBS), and then each sub-effectiveness / cost /time targets are established. These sub-effectiveness / cost / time targets are confirmed as subsystem design criterions.

2. During design progress, it should promptly compare specified effectiveness / cost / time targets and sub-effectiveness / cost / time targets with expenditures in finished design work. At same time, it should conduct the trade-off and optimization in system LCC and system effectiveness and so that take measures to reduce LCC. Once in production it is important to maintain good tracking system to assure that the configuration is built as design.

3. It should take system effectiveness / cost / time as an evaluation means.

From above that, the widely practiced aspect of design-to-effectiveness / cost / time process are the effectiveness / cost / time targets and tracking system. The system effectiveness / cost / time targets establishing is depend upon the VSASAD. By tracking system, it could provide the effectiveness / cost / time information for updating the base of VSASAD as well as providing up to date information on effectiveness / cost / time status as we continue through the design process. During design progress, production plans must be reviewed and trades performed to maintain efficiency. Testing and quality control procedures must be established early and continually reviewed to assure that the system will meet the program goals. Effectiveness / cost / time tradeoff will provide for the best maintenance concept to be design to and followed during the operation and support phase of the program. it is important to feedback data on actual operations in the fiels to provide for improvement in current and future design programs. So that a kind of practiced VERT Simulation Analysis System For Aircraft Design (VSASAD) can be constructed. The structure of VSASAD is presented in Fig.1. By means of friendly interactive interface of VSASAD, the designer can conduct programming, monitoring, controlling and dynamic in-time management of engineering system.

III. THE VERT MODEL

The Steps of the VERT Process

There are five basic steps in a VERT analysis process. It may require several iterations before the model accurately depicts the real-world situation.

Step 1 It is to define the decision / risk situation to be analysed and to specify the objectives of the analysis.

Step 2 A graphic flow network with a generalized networking approach is depicted, and then the flow network transfer into a VERT network (Fig.2).

Step 3 The date (time, cost, and performance)

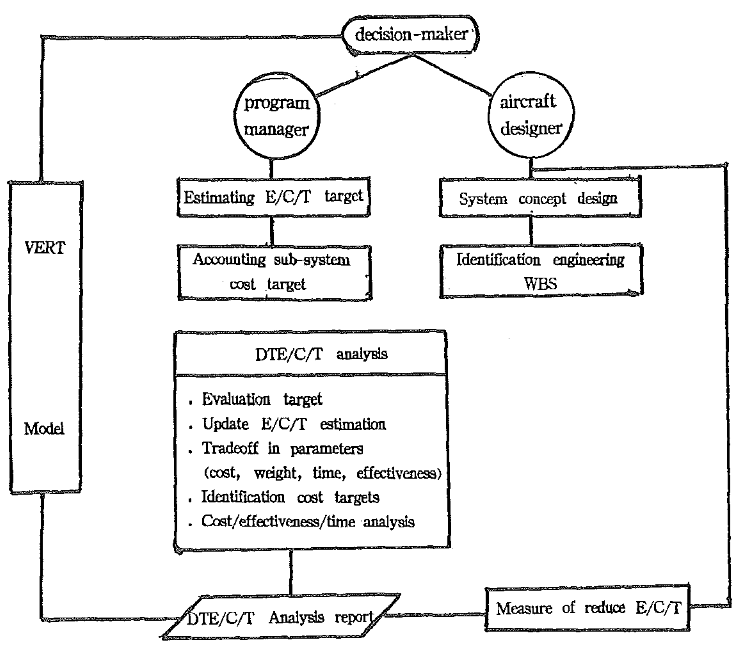

Fig 1. VSASAD

necessary to describe the activities and decision processes should be collected, this data is then organized into some form of a probability distribution or is described by a mathematical equation.

Step 4 This step is to transform the network developed in Step 2 into a VERT model. After the transformation has been effected, the information is entered in a computer program and the simulation is run.

Step 5 The final step is analysis of the simulation results and then analysis of all the information will provide the decision maker.

Description of VERT

VERT is a stochastic network tool which utilizes simulation as a means of deriving solution. It has an extensive array of logical and mathematical feature which make it possible to analyse complex systems and problems. The VERT can treat time, cost, performance (effectiveness) parameters. The VERT needs construct a network (Fig.2), which denotes a pictorial, schematic flow device in which the nodes channel or gate the flow into arc(s) that carry the flow from an input node to an output node. Flow through the network represents the actual completion of those activities and milestones which the flow has traversed. These flows are usually characterized by the parameters of a project time, cost, and effectiveness.

Arcs (lines) and nodes (squares) are used to symbolitically structure the network model. Arcs have a primary and cumulative set of time(T), cost(C) and performance(P) value associated with them while nodes have only the cumulative set. The primary set represents the time expended, cost incurred, and composite performance generated to process all the arcs encountered along the path the network flow came through in order to complete the processing of the arc or node in project.

VERT has two types of nodes, which either start, stop or channel the network flow. The first, split-logic nodes it has separate input and output logic which invokes specific types of input and output operations. The second, single-logic nodes — it covers

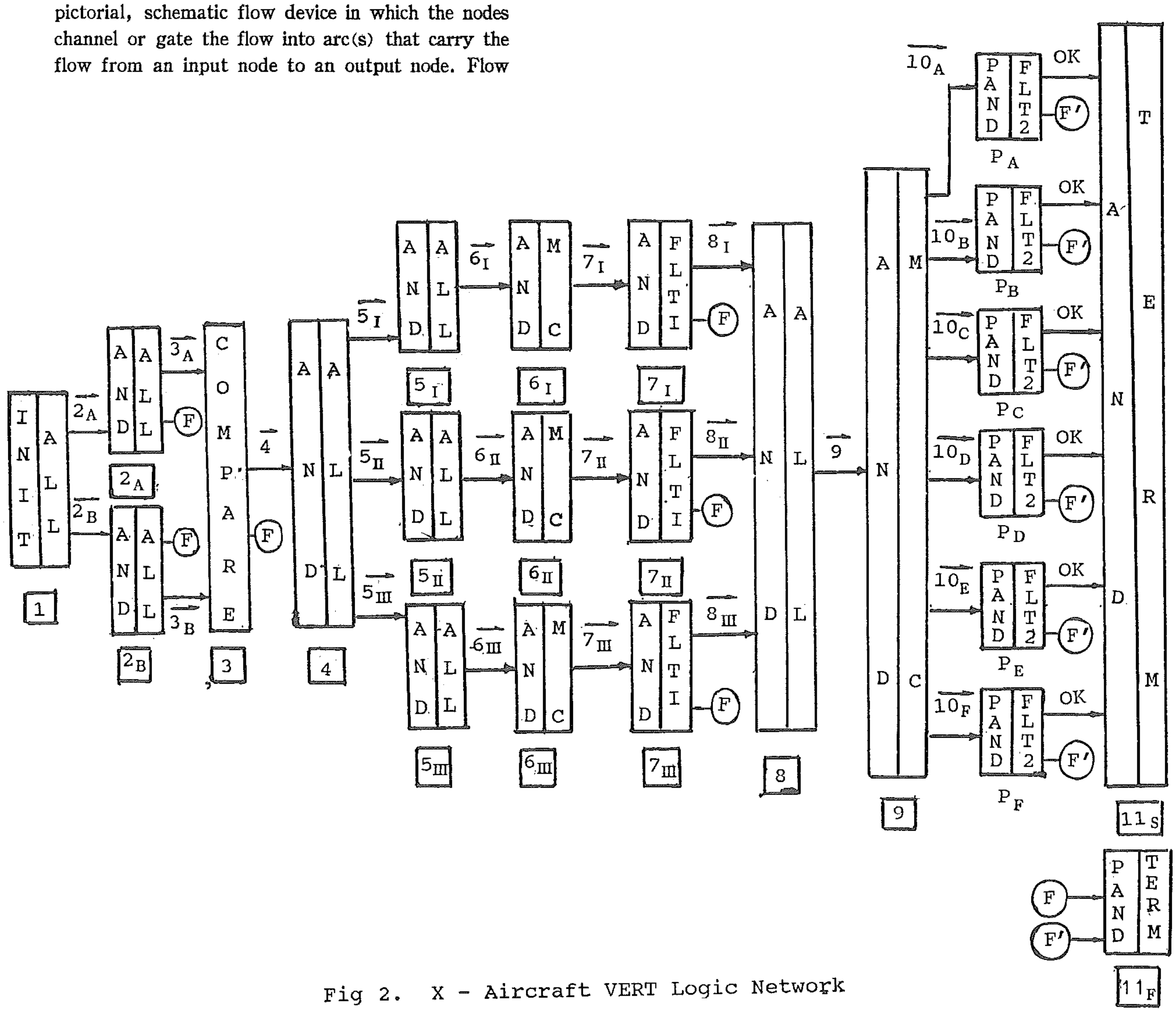

Fig 2. X - Aircraft VERT Logic Network

both input and output operations, simultaneously.

There are four basic input logic available for the split-logic nodes:

1. INITIAL input logic serves as a starting point for the network flow, which completive probability is Fo = 1.

2. AND input logic require all the input arcs to be successfully completed before the combined input network flow is transferred over to the output logic for the appropriate distribution among the output arcs.

3. PARTIAL AND input logic is nearly the same as AND input logic except that it requires a minimum of one input arc tobe successfully completed before allowing flow to continue on through this node. However, this logic will wait for all the input arcs to come in or be eliminated from the network before processing.

4. OR input logic is quite similar to the PARTIAL AND logic. It also require just a minimum of one input arc to be successfully completed before allowing the flow to continue on through this node. This logic will not wait for all the input arcs to come in or be eliminated from the network before the flow is processed.

There are six basic split-node output logics available to distribute the network to the appropriate output arc(s).

1. TERMINAL output logic serves as an end point of the network. It is a sink for network flow(s).

2. ALL output logic simultaneously initiates the processing of all the output arcs.

3. MONTE CARLO (M.C) output logic initiates the processing of one and only one output arc per simulation iteration by the use of the Monte Carlo Method. This means that output arcs are initiated randomly by user-developed probability weights that are placed on these output arcs

4. FILTER 1 (FLT 1) output logic initiates one or a multiple number of output arcs depending on the joint or singular satisfaction of the T+/C+/P (time and/or cost and/or performance) constraints placed on this node's output arcs.

5. FILTER 2 (FLT 2) output logic is the same as FLT 1. except that only one constraint, rather than one to three constraints, can be placed on the constraint bearing output arc, and only PARTIAL AND input logic may be used with FLT 2 output logic.

6. FILTER 3 (FLT 3) output logic employs constraints which are not boundary values but, rather, consist of the name(s) of previously processed arcs. These constraint arcs are prefixed with a plus (+) or a minus(-) sign. The plus(+) sign represents that arc must have been successfully processed before the output arc being constrainted can be initiated. The minus(-)sign represents that arc must have failed to be successfully processed or eliminated from the network before the output arc being constrainted can be initiated for processing.

Four single-logic nodes are as following:

1. COMPARE node logic. The COMPARE node selects the optimal output arc set for processing by weights entered for time, cost and performance.

2. PREFERRED node logic. The PREFERRED node gives preference to the first input — output arc combination over the second and the second is given preference over the third etc..

3. QUEUE node logic. The QUEUE node has the function of transferring network flows in a queueing manner from an inpur arc to its mating output. As the network flow in the live input arcs arrive, they are queued up and sequentially processed by the sever (s).

4. SORT node logic. The SORT node has the purpose of transferring flow from input arcs to output arcs by sorting using time and/or cost and/or performance sort weights.

IV. A CASE STUDY

The X - Aircraft

The example in this paper illustrated the application of VERT (VERT-3) to a new-aircraft (X-AIRCRAFT) development decision.

S Aircraft Manufactury Company will develope a new type aircraft, the company must estimate the probability of successfully developing the new aircraft. Estimates of the following are also desired.

(1) The performance of the new aircraft is required as:

Performance	Goal	Requirement
1. Maximum Speed Speed (Max "M") (P_A)	2.15	2.1
2. Ceiling (Km) (P_B)	18.00	17.90
3. Take -off distance (M) (P_C)	850	900
4. Landing	550	600

distance (M) (P_D)

5. Range (Km) (P_E) 1450 1500

6. Circling
Radius (M) (P_F) 1300 1250

(2) The company can not afford to spend more than 38.80 million (yuan) on this project.

(3) The project should be completed in 85 months. The performance, cost and time equations of the new project as table 1.

VERT Network

The VERT network of this problem as illustrated in figure 2.

The project will consist of three major phases: concept design, structure design and manufacture, system test. In the concept design phase (nodes 1, 2, 3), two design groups will be simultaneously work in parallel efforts on two different but equally desirable designs. The concept design that is the first to be conceptualijed and computer evaluated will be manufacturied. Futher, the optimal concept design is selected. In this phase, the nodes and arcs of the network as follows:

Node 1, (Node START) initiates two parallel independent concept design efforts. Arc $\overrightarrow{2_A}$ and $\overrightarrow{2_B}$ represent the concept design effort by two different groups.

Node 2_A and 2_B individually route their input flows to either a success path (arc $\overrightarrow{3_A}$, $\overrightarrow{3_B}$) or a fail path (arc F), depending on whether their lone input arc was a success path or a failure.

Node 3. with its COMPARE unit logic, which selects the optimal output arc set for time, cost and performance.

The structure design and manufacture phase consist three subsystem design and manufacture —— engine (subsystem I), aircraft structure (subsystem II) and control systems (subsystem III).

Node 4. and arc 4. represents overall aircraft design. Node 5_I, 6_I, 7_I, 5_{II}, 6_{II}, 7_{II} and 5_{III}, 6_{III}, 7_{III}, arc 5_I, 6_I, 7_I, 5_{II}, 6_{II}, 7_{II} and 5_{III},

Major Activity	Completion Time					Completion Cost
	Distribute type	Exp	σ	Min	Max	
1. Engine Trial-Manufacture	Nomal	2.75	0.1	2.5	0.35	$C=1297+144t+\frac{115.8}{1.6^t}$
2. Engine test	Nomal	0.25	0.05	0.2	0.35	$1284e^{-t}+1000^t$
3. Flight Controls Trial Manufacture	Nomal	3.33	0.01	3.3	3.35	$500+186.5^t$
4. Rader Trial Manufacture	Nomal	3.33	0.1	3.3	3.35	$500+186.5^t$
5. Radio System Trial Manufacture	Nomal	2.70	0.01	2.50	2.95	$840+50^t+12210\ 10^t$
6. Tool and Assembly Jig Manufacture	Nomal	0.17-0.25	0.05	0.20-0.24	0.17-0.32	$(150-450)+67t$
7. Part Make	Nomal	0.25-0.5	0.005-0.1	0.20-0.45	0.26-0.80	$100+67t$
8. Initial Assembly	Nomal	0.083	0.02	0.08	0.2	$150+67e^{t-0.083}$
9. Wing, Tail and body Assembly	Triangular	0.23		0.19	0.46	$50+72e^{t-0.21}$
10. Final Assembly	Nomal	0.11-0.33	0.05	0.15-0.085	0.15-0.42	$(200-450)+(330-1300)\ t-0.33)+1$
11. Test flight	Nomal	1.5	0.08	1.0	2.5	$0.3\ 600+457+66.7t$
12. System Test	Triangular		0.3-0.50	0.10-0.49	0.27-0.58	$(50-200)$

Table 1

6_{III} , 7_{III} represent structure design, manufacture and its test of the subsystem I, II, III respectively. Node 8. and arc $\overrightarrow{8_I}$, $\overrightarrow{8_{II}}$, $\overrightarrow{8_{III}}$ complete the final assembly. Third phase is the system test (arc $\overrightarrow{9}$. and node9.). Arc $\overrightarrow{10_A}$, $\overrightarrow{10_B}$, $\overrightarrow{10_C}$ $\overrightarrow{10_D}$, $\overrightarrow{10_E}$, $\overrightarrow{10_F}$, and node P_A P_B P_C P_D P_E P_F represent the results of the performance.

OK arc receives the acceptable flows from node P_A, P_B , P_C , P_D , P_E or P_F. F' arc receives the unacceptable from node P_A, P_B, P_C, P_D, P_E or P_F.

Node 11 catches all completions not routed to the failure node. Node 11 catches all completions filtered out by any one of the six check nodes.

Results

The selected output reports reflecting the 1000 simulation iterations of the input data on the VERT network are shown in Table 2.

Performance		Goal	Require-ment	Mean	Mode	Probability of failure
1. Maximum Speed (Max "M")	P_A	2.15	2.1	2.113	2.112	6.8%
2. Ceiling (KM)	P_B	1800	17.90	18.13	18.11	11%
3. Take-off distance (M)	P_C	850	900	851.9	845	35.6%
4. landing distance (M)	P_D	550	600	546.5	543.6	10.3%
5. Range (KM)	P_E	1450	1500	1303	1305	48.4%
6. Circling Radius (M)	P_F	1300	1250	1353	1349	

Table 2

Reference

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