RESULTS OF A UTILITY SURVEY OF THE STATUS OF LARGE WIND TURBINE DEVELOPMENT

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INTRODUCTION

A survey of the status of wind turbine development has been commissioned by a utility company having interest in the application of wind power to the generation of electricity. The utility, Hydro-Quebec, is considered one of the major utilities in North America in that it services one of the largest geographical land masses in the continent. An indication of the scope of the utility is given by Table I.

SURVEY TEAM

The survey was carried out by a group of researchers drawn from three distinct and complementary fields as shown below.

Type	Organization	Related Work
Consulting Engineering	The Shawinigan Engineering Co. Ltd., Montreal.	Energy and Power Consultant, Design, Engineering and Project Management of Power Projects for Utilities.
Utility	L'Institut de Recherche de l'Hydro-Québec, Montreal. (IREQ)	R & D on energy production, transmission, storage and utilization.
Manufacturing Industry	Canadair Limited, Montreal.	Analysis, Design and Manufacture of aerospace structures.

Related Team Experience

- IREQ work on wind energy since 1970
- Design and operating experience of 230 kw VAWT
- Design studies on units rated up to 10,000 kw

METHODOLOGY

The overall objective was established as:

Examine Wind Energy Conversion Systems (WECS) from a utility viewpoint to establish the state-of-the-art with regard to:

- Availability of the type of machines
- Quality of power generation
- Suitability of WECS for electrical grid systems
- Reliability of the WECS
- Economics

The methodology employed consisted of:

- Survey of literature in the public domain
- Visit to installations of interest in Europe and North America.
- Discussion with Designers, Operators and Planners
- A design study involving state-of-the-art WECS

RESULTS

Table II provides summary data for those wind turbine generators (WTG's) covered by the survey and includes machines which exist or are projected, and for which data is available. Those machines marked * were visited by representatives of the three companies. The personnel concerned with demonstrating and discussing the various machines were most co-operative and their assistance is gratefully acknowledged. Figure 1 presents a size comparison of six of the large (over 1000 kw rating) HAWT's in the survey.

Figure 2 presents a size comparison of eight smaller HAWT's.

Figure 3 shows a size comparison of the VAWT's included in the survey. Note the scale of the smaller machines.

Figures 4 and 5 show schemes for large VAWT's conceived as proposals for the Canadian Government.

In addition to the HAWT's and VAWT's the study briefly examined four innovative concepts, the Vortex Augmentor, the Tornado Tower, the Madaras Rotor and the Diffuser Augmented Wind Turbine.

DISCUSSION OF RESULTS

Of the twenty three designs listed in Table II, seven are VAWT's, nine are upwind HAWT's and seven are downwind HAWT's.

Of the total group, seven are of a rating which would be of real interest to a utility (Figures 2 & 4) and,of these, one is a VAWT, (the Canadian Government Proposal); four are upwind HAWT's and two are downwind HAWT's. The largest of the group, the German GROWIAN is a design concept, while the Wind Power Group unit is in the design stage. Three machines, Mod 1, Mod 2, and the WPPC design are in the manufacturing/ installation stage. Only one, the Danish Tvind HAWT is actually in operation. As of October 1978, this unit had been operated up to 400 kw, 23% of its rated power, and so far as is known is the largest unit both in size and design rated power in existence.

The smaller HAWT's (below 630 kw), shown by Figure 3, range from the Danish Gedser machine with its derivatives Mod A and Mod B, through the Mod 0, Mod 0A series and the WTG Cuttyhunk machine, to the FDO unit being designed in the Netherlands. The lower end of this scale is occupied by the Saab-Scania unit which is a test bed for the 2000-4000 kw Swedish Government design study, and the Lawson-Tancred machine in the UK which has an innovative transmission system and power storage facility.

VAWT's are represented by the Canadian NRC/DAF Darrieus type, soon to recommence test operations in the Magdelen Islands, the similar concept Sandia 17 meter diameter rotor unit and the 5.5 meter diameter rotor Fokker machine. A hybrid approach is shown by the Dornier unit with its mixture of Darrieus and Savonius rotors, while the variable geometry VAWT is illustrated by the design developed by Reading University. Finally, the Giromill is included as representing the only vertical axis design to employ variable pitch blades.

All these units are the possible forerunners of much larger machines and are therefore of interest to a utility.

The design state-of-the-art was reviewed and it became apparent that the HAWT is more advanced than the VAWT and that different design philosophies are represented by the various machines existing today. No clear indication exists as to which concept will produce the most cost effective system. However, it is clear that the present-day designs show that large WECS are technically feasible and that in a wind regime of, say 8m/sec mean wind speed, at 30 m height, a system can be made to be cost effective when compared with equivalent electrical energy obtained from diesel oil.

One of the operating features necessary for utilities will be the capability of a WECS to operate throughout all types of weather, including icing. It is noted that none of the machines listed has the capability of deicing the rotor blades.

Reviewing the spectrum of WECS existing today or planned for the next two or so years, it is clear from a utility viewpoint that the technology has not developed to the point where a utility could write a procurement specification to which a manufacturer could respond on a production basis.

Existing constant speed machines, directly connected to the electrical network do not fully meet utility requirements from the viewpoint of quality of power generation. However, with utility company participation it appears feasible to design machines which will meet these requirements.

Figure 6 presents the major events of the last six years and a projection as to when the HAWT's and a VAWT will have demonstrated design reliability and performance.

This suggests that by the early to mid 1980's it is possible that one or more production systems could be available, which, with suitable influence by the utilities during the design stages, could be on site and operating so that wind power could begin to pay its way and make a fair return in the utility marketplace whilst extending to a considerable amount the use of non-renewable energy.

When considering the economics of owning and operating large size WECS, the following factors have to be taken into account.

1. Basic design of the machine
2. Suitability of the design with respect to:
   a) wind regime at potential sites
   b) employing electrical or equivalent storage facilities
   c) integration into the existing grid system
   d) application to the wind farm concept
3. The WECS design power rating and the projected electrical power production in kwh for the potential sites
4. Wind site data
5. Site preparation costs
6. Installation costs including site access
7. Maintenance and operating costs
8. Long life (minimum 30 years) with minimum replacement costs.

With the above factors optimized or near optimized for the 30 years system life, application of wind power to the production of electricity by utility companies can become economically attractive. The key aspect, it is felt, is to involve utilities, consultants and the manufacturing industry in the entire process of design.

CONCLUSIONS

1) There is a growing interest in the Western European countries and North America in the WECS and their utilization for the generation of electrical power.

2) HAWT are more advanced in design and in operating experience than VAWT units. Both concepts show promise of technical and economic viability but, as yet, there are no clear cut conclusions as to which is the better concept.

3) Results of the various studies examined indicate that the present-day designs of large WECS are technically feasible and that in an 8 m/s meanwind speed appear capable of producing a cost effective system when compared with diesel units fuelled at present-day oil prices.

4) Existing constant speed machines, directly connected to the electrical network do not fully meet utility requirements from the viewpoint of quality of power generation. However, it appears feasible to design machines to meet the utility requirements.

5) The present-day designs appear to have a grid penetration limitation of about 10 to 15 percent without additional energy storage. Utility interest in WECS depends upon the amount of grid penetration capability of the WECS design.

6) The present-day designs of the WECS are still, in our opinion, preliminary designs and require design and cost optimization to be suitable for utility acceptance.

7) Based on the survey of the present-day development programs, it appears that the potential of large WECS will be established in the period 1983 - 1985.

DISCUSSION

Q. What is the height, power and diameter of the chosen design?

A. The height of the chosen design was 100 meters from the ground. The distance from the bottom bearing to the top bearing was 96 meters and the rotor diameter was 64 meters. The power was 3,900 kilowatts, and the output will be on the order of 7,500,000 kWh per year.

Q. I talked to a young man from Quebec in May that was, I think, actually operating a three-bladed 30-foot diameter horizontal axis machine. Could you give me some information on what's going on in that area of work?

A. The gentleman concerned, Mr. A. Watts of Hydro-Quebec is immediately in front of you, and he has more information on that than I have.

Q. Could you discuss the control of these machines?

A. The large vertical machine which we looked at will be grid-controlled with a constant rpm locked into the grid. So the actual control would be the normal control of the Darrieus turbine with a given rpm.

Q. If you had large installations of these, say, of five to a hundred megawatts, is that type of control accessible to your utility?

A. Yes, certainly. That would be the way we would propose to go, because we have a very strong grid in the province of Quebec, and we don't see this machine replacing hydro power very much. We would regulate the rpm by synchronizing with the grid. I agree there could be a lot of discussion about the best way to do it, but that is the way we see it at the present time.

TABLE I. - HYDRO-QUEBEC

OWNERSHIP: Government-owned utility

TYPE OF GENERATION: 99.7% Hydro 0.3% Others

SYSTEM PEAK IN 1979: About 16,000 MW

TRANSMISSION SYSTEM: 25,000 kM of circuits rated between 69 - 735 kV.

R & D: L'Institut de Recherche de l'Hydro-Québec (IREQ)

REASONS FOR INTEREST IN WIND ENERGY:

- Large potential for wind energy (55,000 MW)
- Reduce dependence on imported energy forms
- By 1990 most of the potential Hydro sites will have been exploited.

TABLE II. - WTG SURVEY

NAME	COUNTRY	STATUS (late 1978)	DESCRIPTION Type	Blades	Rating, kw
Gedser*	Denmark	Test	Upwind HAWT	3	200
Mod A	"	Proposal	" "	3	630
Mod B	"	Proposal	" "	3	630
Tvind*	"	Test	Downwind HAWT	3	1724
Dornier*	W.Germany	Test	VAWT Darrieus & Savonius	3 - 2	20
GROWIAN	"	Design	Downwind HAWT	2	2000-3000
Fokker*	Netherlands	Test	VAWT Darrieus	2	15
FDO	"	Design	Upwind HAWT	2	300
Saab-Scania*	Sweden	Test	Downwind HAWT	2	63
Swedish Gov't	Sweden	Proposal	Downwind HAWT	2or3	2000-4000
Lawson-Tancred	UK	Test	Upwind HAWT	3	30
WPG (a)	UK	Design	Upwind HAWT	2	3700
Reading* Univ.	UK	Test	VAWT	2	1
Mod 0*	USA	Test	Downwind HAWT	2	100
Mod OA	USA	Test	Downwind HAWT	2	200
Mod 1	USA	Installation	Downwind HAWT	2	2000
Mod 2	USA	Design/ Manufacture	Upwind HAWT	2	2500
WPPC*(b)	USA	Design/ Manufacture	Upwind HAWT	3	3000
WTG	USA	Test	Upwind HAWT	3	200
Sandia	USA	Test	VAWT Darrieus	2or3	60
Giromill	USA	Design	VAWT	3	40
NRC/DAF*	Canada	Test	VAWT Darrieus	2	230
Cdn.Gov't.	Canada	Proposal	VAWT Darrieus	2or3	3800

* Machines visited
(a) Wind Power Group
(b) Wind Power Products Corp.

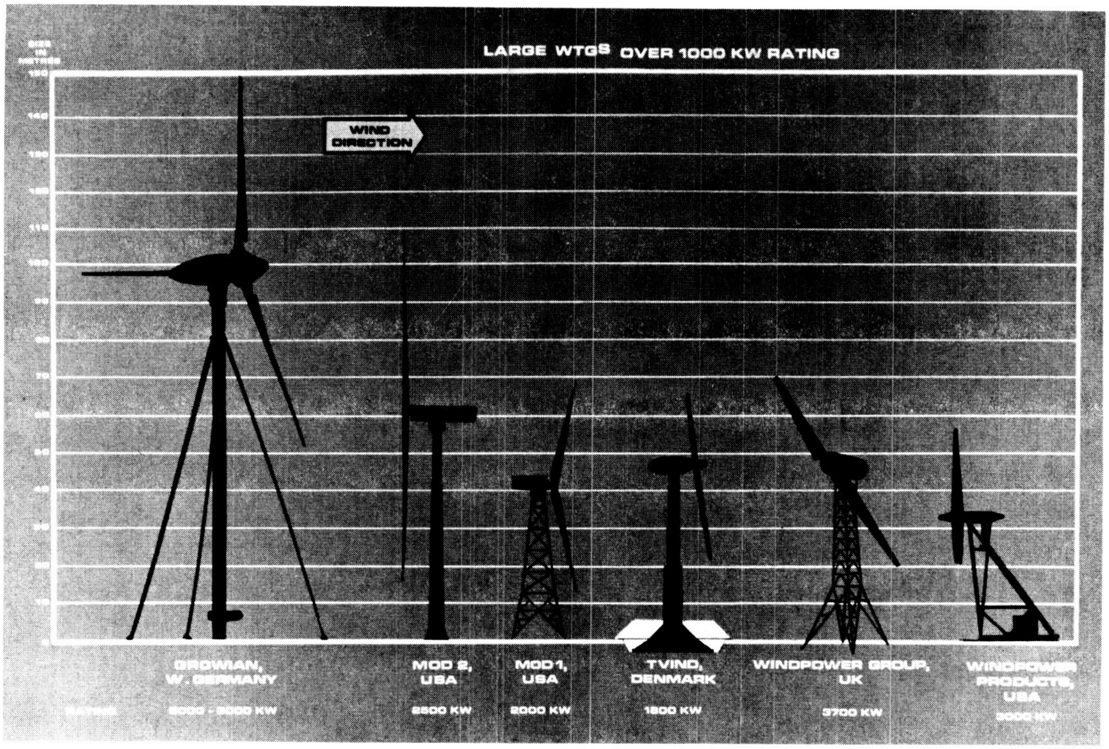

Figure 1

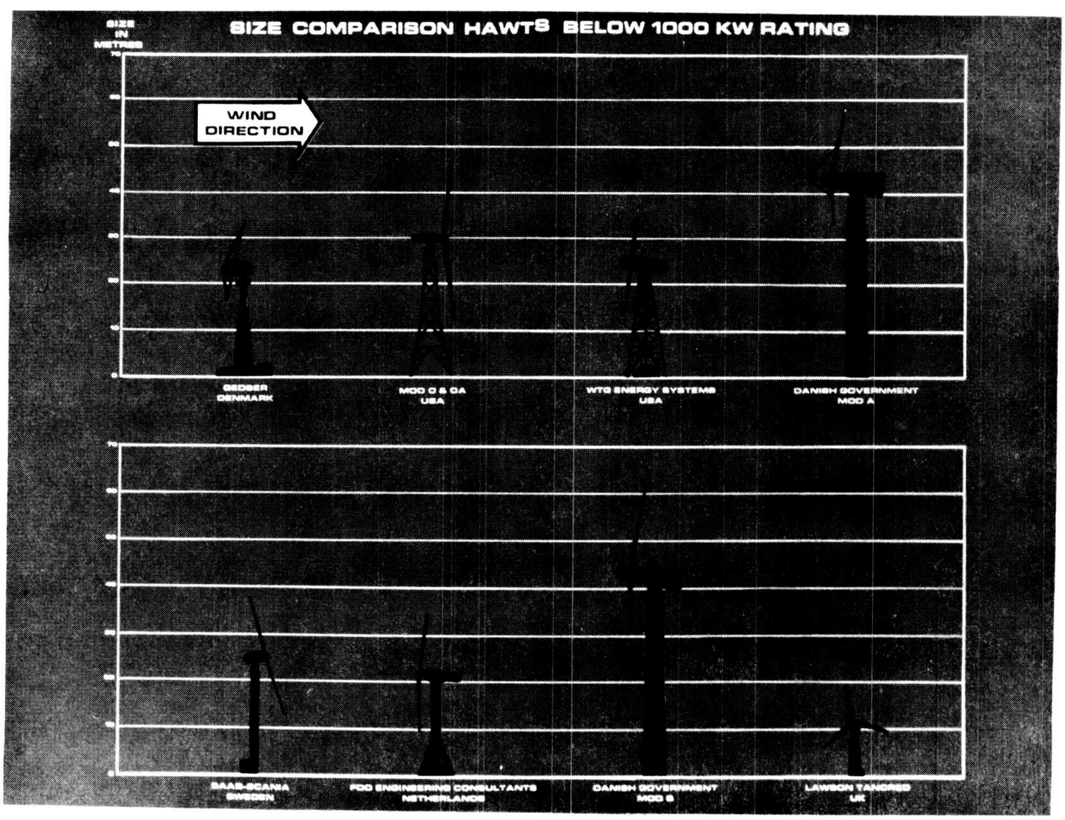

Figure 2

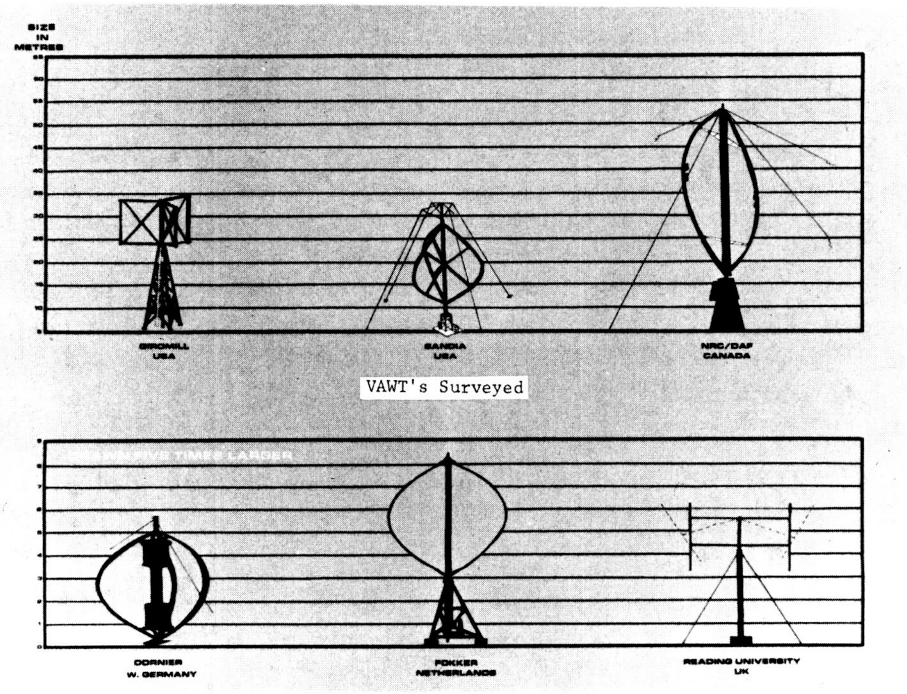

Figure 3

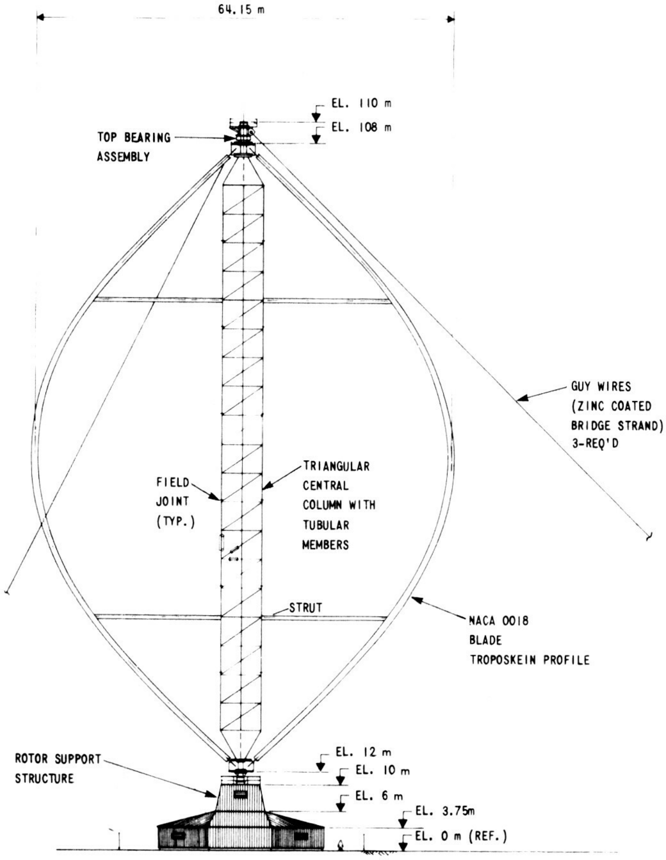

Figure 4. - Proposed Large VAWT.

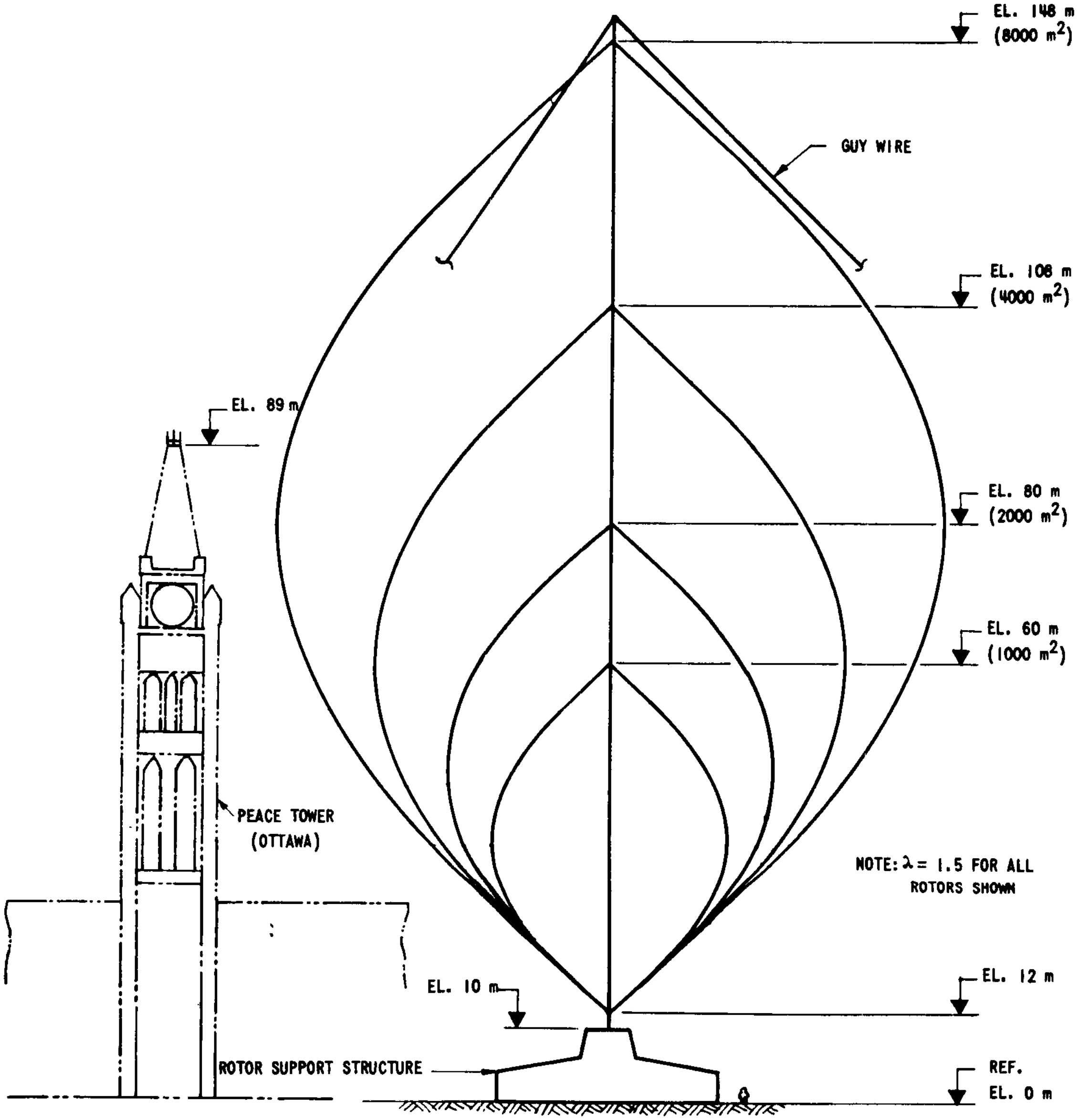

Figure 5. - Rotor size for 1000, 2000, 4000 and 8000 m^2 swept area.

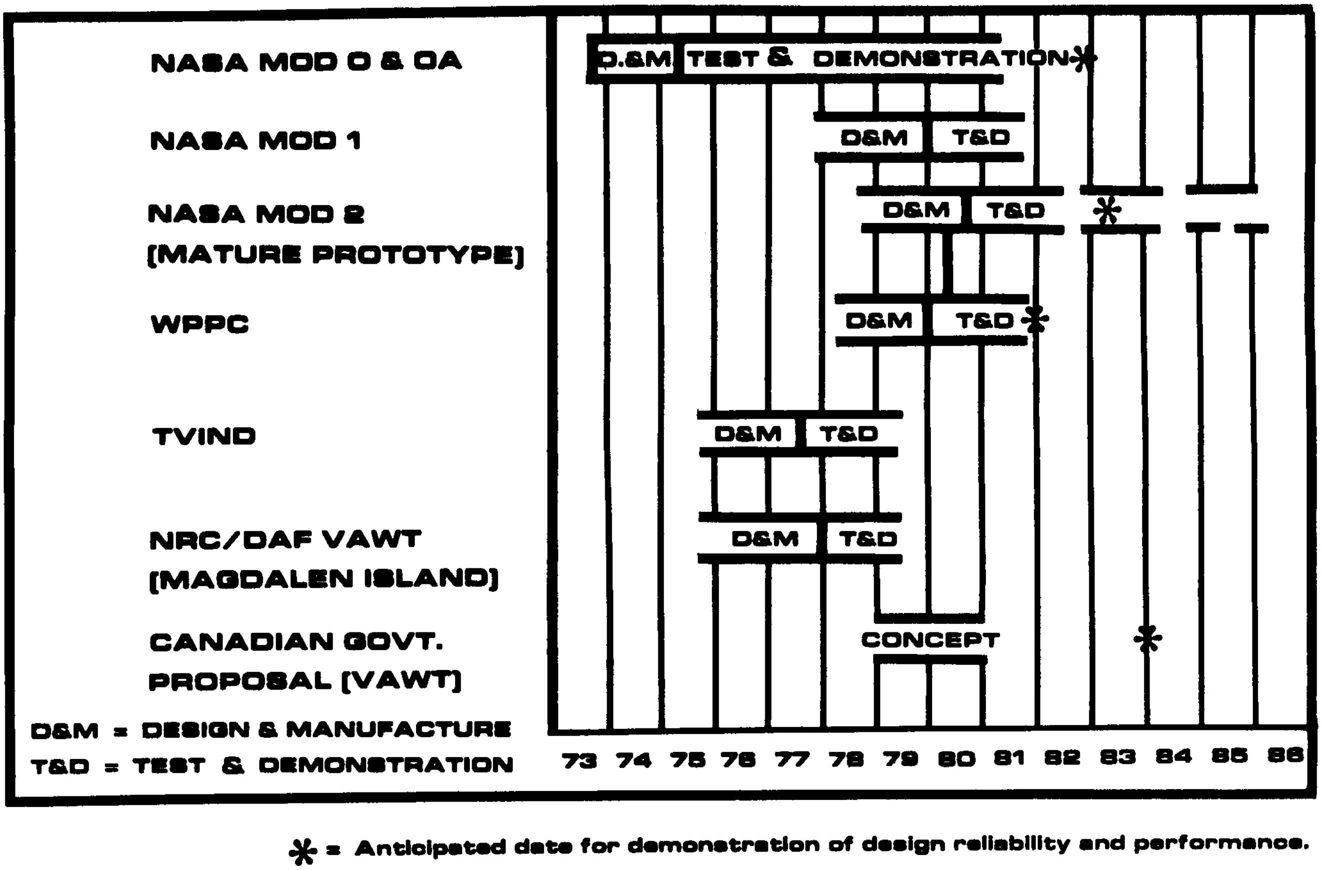

Figure 6. - Recent Major Events.