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Comparative Study of Various Types of
VTOL Transport Aircraft
PERFORMANCE AND WEIGHT ESTIMATES
FOR SIX VTOL AIRCRAFT REPORT R-83

Vertol Aircraft Corporation Morton, Pennsylvania



Research and Development Program

Contract NONR 1681(00)

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JULY 13, 1956

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I. SUMMARY

This report includes the final performance and weight estimates for the six VTOL aircraft found most promising in the general configuration studies of reference (a) and previously reported in reference (b). The following six configurations were determined to be most suitable for fulfilling the transport mission requirements at speeds of 300 mph or greater:

1. Tilt Wing Propeller
2. Tilting Ducted Propeller
3. Vectored Lift
4. Special Hovering Turbojet
5. Vertodyne
6. Vectodyne

The summary of weights and performance on the following page indicate the first three configurations have approximately equal capability at the specified cruising speed of 300 mph with the vectored lift design resulting in a higher gross weight because of its relative inefficiency for VTOL operation. The latter three configurations, considered most promising for high speed, give an indication of the gross weight growth accompanied with the combination of VTOL capabilities and increased forward speed potential. With regard to speed it can be seen that the Special Hovering Turbojet does have relatively low forward flight performance as a result of the minimum number of engines installed for forward thrust. It was felt that the maximum forward speed requirement of 375 mph should be sacrificed for this concept since all other mission requirements were met with the chosen power plants. The 375 mph speed could be met simply by installing a forward flight power package capable of greater thrust with a corresponding increase in the normal gross weight.

The Vertodyne, from a gross weight point of view, appears more promising than the Vectodyne for this particular mission with the former being penalized considerably for cruising at 10,000 feet. Because of its large wing area the Vertodyne is, of course, more suitable to cruising at altitudes higher than the mission requirement as can be easily seen in reference (c).

The summary of weights and performance is shown on the following page for the basic transport mission. A more complete picture of the performance capability of each configuration can be found in the Characteristics Charts presented in the body of the report.

SUMMARY OF PERFORMANCE AND WEIGHTS

WEIGHTS:		TILT-WING PROPELLER	TILTING DUCTED PROPELLERS	VECTORED LIFT	SPECIAL HOVERING TURBOJET	VERTODYNE	VERTODYNE
Units							
Lbs.		88899	93270	111313	107286	113959	121700
Lbs.		6037	62860	78863	51506	66910	22130
Lbs.		28862	30410	32450	55790	47048	47410
Lbs.		600	600	600	600	600	600
Lbs.		8000	8000	8000	8000	8000	8000
Lbs.		18120	19690	21320	44750	37510	37950
Lbs.		1850	1850	2480	12500	3725	2785
Lbs.		16270	17840	16840	32250	33785	35165
Lbs.		300	300	400	1360	300	450
Lbs.		460	460	300	--	300	360
Lbs.		432	390	580	1020	288	850
Lbs.		900	920	1200	0	0	1350
Lbs.		50	50	50	50	50	50
		Allison 550-B1	Allison 550-B1	Allison 550-B1	General Electric J-85	General Electric J-79	Allison 550-B1
		6	6	8	(60-hover 8-fwd.)	4	9
		Turboprop 5168 SHP	Turboprop 5168 SHP	Turboprop 5168 SHP	Turbojet	Turbojet	Turboprop
		5168 SHP	5168 SHP	5168 SHP	2450 Lbs.	10000 Lbs.	5168 SHP
		4590 SHP	4590 SHP	4590 SHP	2000 Lbs.	9700 Lbs.	5168 SHP
							4590 SHP
mph		436	424	450	364	506	450
mph		440	424	455	347	500	450
mph		300	300	300	300	400	345
mph		300	300	300	300	400	345
NRP Ft/Min		7100	6660	7600	800	3660	5850
Ft/Min		5900	5600	6400	320	2550	3450
Min.		1.54	1.63	1.43	17.7	3.40	2.11
Ft.		43000 (1)	42200 (1)	39800	13600	37000	24000
Ft.		6000 (1)	6000 (1)	6000 (1)	6000	6000	6000 (1)
S. Miles		425	425	425	425	425	425

NOTES: (1) With water injection
(2) Mfg's SFC increased 5% - 2 Mins W/U @ NRP - 5 Mins Hovering @ Radius Midpoint - 10% Reserve

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II. INTRODUCTION

The performance analysis used in the preparation of the data presented throughout this report follow the accepted methods as outlined, for instance, in reference (c). The only exception is the method of analysis used for the Vectodyne which employs the Aerodyne principles and is discussed further in that particular section.

The mission requirements which dictated the normal gross weight for the configurations considered are as follows:

- | | |
|---------------------|--|
| a. Payload | 8,000 lb. out - 4,000 lb. return |
| b. Take-off | Vertical 6,000 ft. at 95°F |
| c. Cabin Size | 8' x 9' x length required for
35 troops |
| d. Cargo | 35 Infantry Troops or equivalent
vehicles |
| e. Cruise Speed | 300 mph |
| f. Flight Profile | 20% of radius adjacent to target
at S.L. |
| g. Landing | Vertical |
| h. Radius of Action | 425 Statute Miles |

Pertinent dimensional data for the six VTOL configurations fulfilling the above mission requirements are shown on Table 1. Table 2 is a consolidated group weight statement indicating the difference between configurations of component weight items. The drag summary on Table 3 similarly gives a minimum breakdown of the component drag items. It should be noted that in the case of the Special Hovering Turbojet and the Vertodyne where a thick section is

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required, the wing drag coefficient reflects the high speed - low drag airfoil as given in the Table of Dimensions.

Standard Aircraft Characteristics Charts have been prepared for each configuration and are shown in the following sections. These charts present a composite picture of each aircraft and as such, provide an easy means for an overall appraisal of the six configurations considered most promising for the military transport mission.

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TABLE 1
DIMENSIONAL DATA

	TILT WING	TILTING DUCTED PROPELLERS	VECTORED LIFT	SPECIAL HOVERING TURBOJET	VERTODYNE	VECTODYNE
General						
Length (Overall)	84 ft 9 in	84 ft 9 in	84 ft 6 in	92 ft 0 in	91 ft 0 in	85 ft 0 in
Fuselage Width (Max)	13 ft 6 in	13 ft 6 in	13 ft 6 in	13 ft 6 in	13 ft 6 in	13 ft 6 in
Height (to Top of Vertical Fin)	37 ft 0 in	37 ft 0 in	32 ft 0 in	35 ft 0 in	35 ft 0 in	33 ft 8 in
Wing						
Span	85 ft 6 in	109 ft*	98 ft 6 in	90 ft	106 ft	
Area	1170 sq.ft	1426 sq.ft**	1430 sq.ft	1400 sq.ft	2284 sq.ft	
Aspect Ratio	6.25	8.35	6.79	5.78	4.91	
Taper Ratio	.498	.776	1.0	.250	.335	
Airfoil	2415	2415	2415	633-018	633-018	
M.A.C.	14 ft 4 in	14 ft 6 in	18 ft	15 ft	24 ft 6 in	
Tail						
Vertical Tail Area	260 sq.ft	260 sq.ft	240 sq.ft	300 sq.ft	240 sq.ft	280 sq.ft
Horizontal Tail Area	320 sq.ft	320 sq.ft	300 sq.ft	300 sq.ft	300 sq.ft	400 sq.ft
Landing Gear						
Tread	13 ft 6 in	14 ft	13 ft 6 in	63 ft 0 in	13 ft 6 in	15 ft 8 in
Wheel Base	24 ft 6 in	27 ft 9 in	32 ft 6 in	35 ft 6 in	26 ft 9 in	24 ft 6 in
Propellers						
Diameter	21 ft 0 in	17 ft 6 in	25 ft 0 in	--	16 ft 8.4 in	18 ft 0 in
Tip Speed	850 fps	12 ft 0 in	850 fps	--	900 fps	900 fps
Disc Loading	64.1	131.5	57.6	--	259	

*Over Ducts
**Includes 50% Ducts

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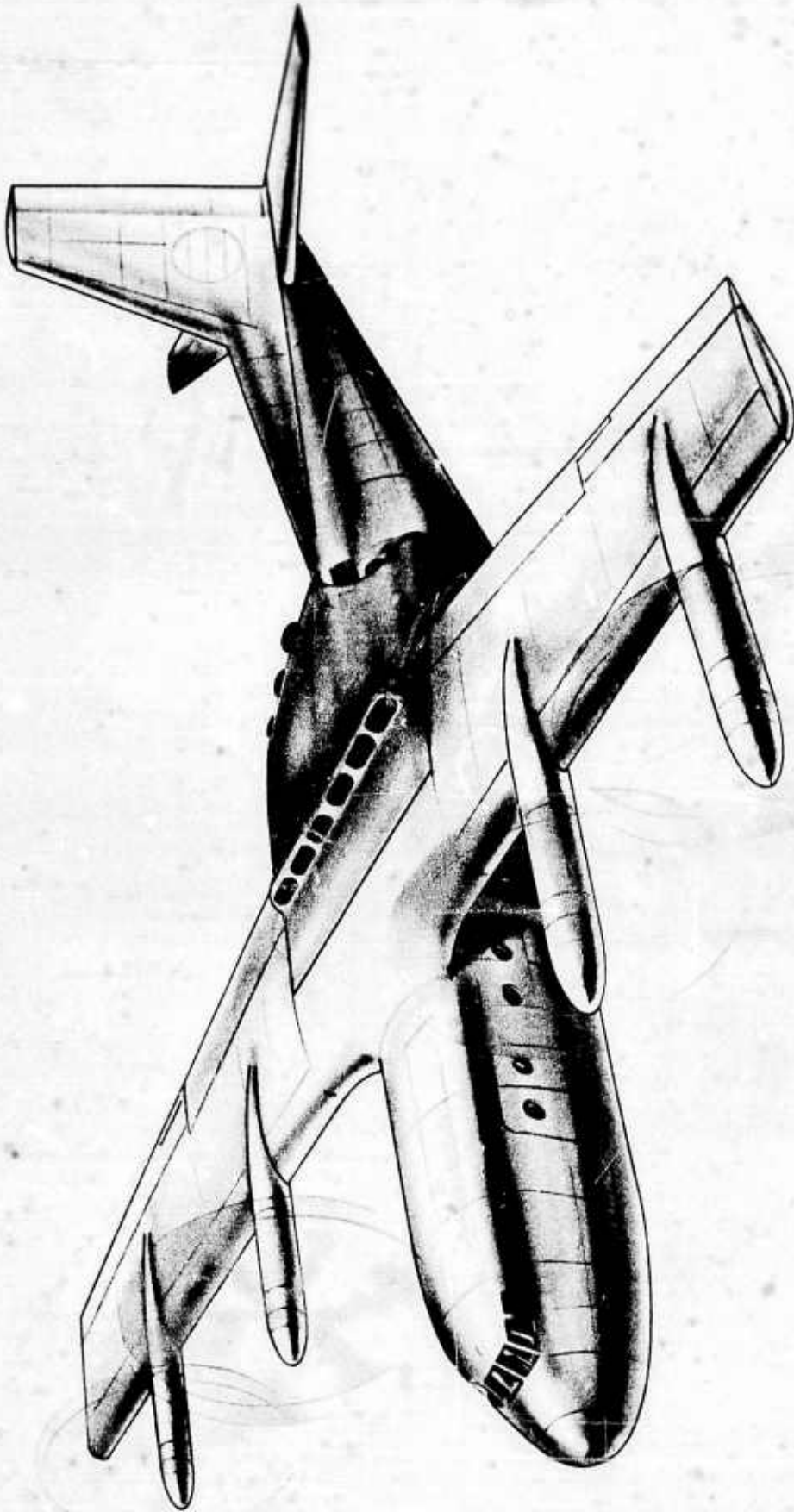
TABLE 2
GROUP WEIGHT SUMMARY

	TILT-WING PROPELLER	TILTING DUCTED PROPELLER	VECTORED LIFT	SPECIAL HOVERING TURBOJET	VERTODINE	VECTODINE
ROTOR GROUP	8736	11155	11328	--	4580	6990
WING GROUP	7275	6940	11650	7060	10600	9100
TAIL GROUP	3150	3150	3780	3750	3960	4200
BODY GROUP	6746	7480	7890	8030	8130	8640
ALIGNING GEAR GROUP	4500	4050	5940	4820	5080	5400
ENGINE SECTION	2710	4530	6030	1620	4730	4750
POWER PLANT	16270	20435	27800	20936	24305	27420
ENGINE ACCESSORIES	12060	12060	6080	15246	12600	6170
ENGINE PLANT CONTROLS	910	910	880	820	800	1270
STARTING SYSTEM	120	120	160	510	160	190
COOLING SYSTEM	680	680	900	1350	400	900
LUBRICATION SYSTEM	150	150	200	--	1400	600
FUEL SYSTEM	1340	1340	1780	1320	800	2010
TRANSMISSIONS	1010	1050	1290	1690	1340	1700
SHAFTING	3470	3040	4640	--	1705	3720
FIXED EQUIPMENT	2210	1085	1870	--	1180	870
INSTRUMENTS	4970	5160	4445	5290	5525	5880
FLIGHT CONTROLS	270	270	360	890	240	300
HYDRAULIC SYSTEM	2200	2250	1425	1575	2650	2880
ELECTRICAL SYSTEM	350	370	390	430	435	480
COMMUNICATION SYSTEM	300	850	850	1050	850	850
FURNISHINGS	300	300	300	300	300	300
MISCELLANEOUS	800	800	800	800	800	800
WEIGHT EMPTY	200	320	220	245	250	270
USEFUL LOAD	60037	62860	78863	51506	66910	72380
CREW	28862	30410	32450	55780	47048	49410
TRAPPED LIQUIDS	600	600	600	500	600	600
ENGINE OIL	432	390	580	1020	288	650
TRANSMISSION OIL	300	300	400	1360	300	450
FUEL	460	460	300	--	300	360
CARGO	18120	19690	21320	44750	37510	7950
MISCELLANEOUS	8000	8000	8000	8000	8000	8000
WATER	50	50	50	50	50	50
GROSS WEIGHT	900	920	1200	--	--	1350
	88899	93270	111313	107286	113958	121790

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TABLE 3
DRAG SUMMARY

	TILT WING	TILTING DUCTED PROPELLERS	VECTORED LIFT	SPECIAL HOVERING TURBOJET	VERTODYNE	VERTODYNE
Wing Area, SW	1170 sq.ft	1426 sq.ft	1430 sq.ft	1400 sq.ft	2234 sq.ft	—
Total Propeller Disc Area						508 sq.ft
Wing (@ $CL_W = 0$)	C_{DSW}	C_{DSW}	C_{DSW}	C_{DSW}	C_{DSW}	C_{DA}
Fuselage	.00770	.00770	.00770	.00540	.00540	.0266
Nacelles	.01075	.00883	.00827	.00899	.0055	.0175
Gear Bumps	.00128	.00133	.00273	.00116	.00192	.00204
Horizontal Tail	.000615	.000505	.000502	.000214	.000315	.00789
Vertical Tail	.00274	.00225	.0021	.00214	.00131	.00551
Engine Inlets	.00222	.00183	.00168	.00214	.00105	.00393
Shrouds	.00141	.00116	.00315	.000428	.000656	.0120
Booms		.00328	.000369			.00709
ΣC_{DSW}	.02672	.02689	.02650	.02047	.01615	
ΣC_{DA}						.08256
Miscellaneous and Interference 15%	.00401	.00403	.00397	.00307	.00242	.01240
Total C_{DSW}	.03073	.03092	.03047	.02354	.01857	
Total C_{DA}						.09496



Standard Aircraft Characteristics

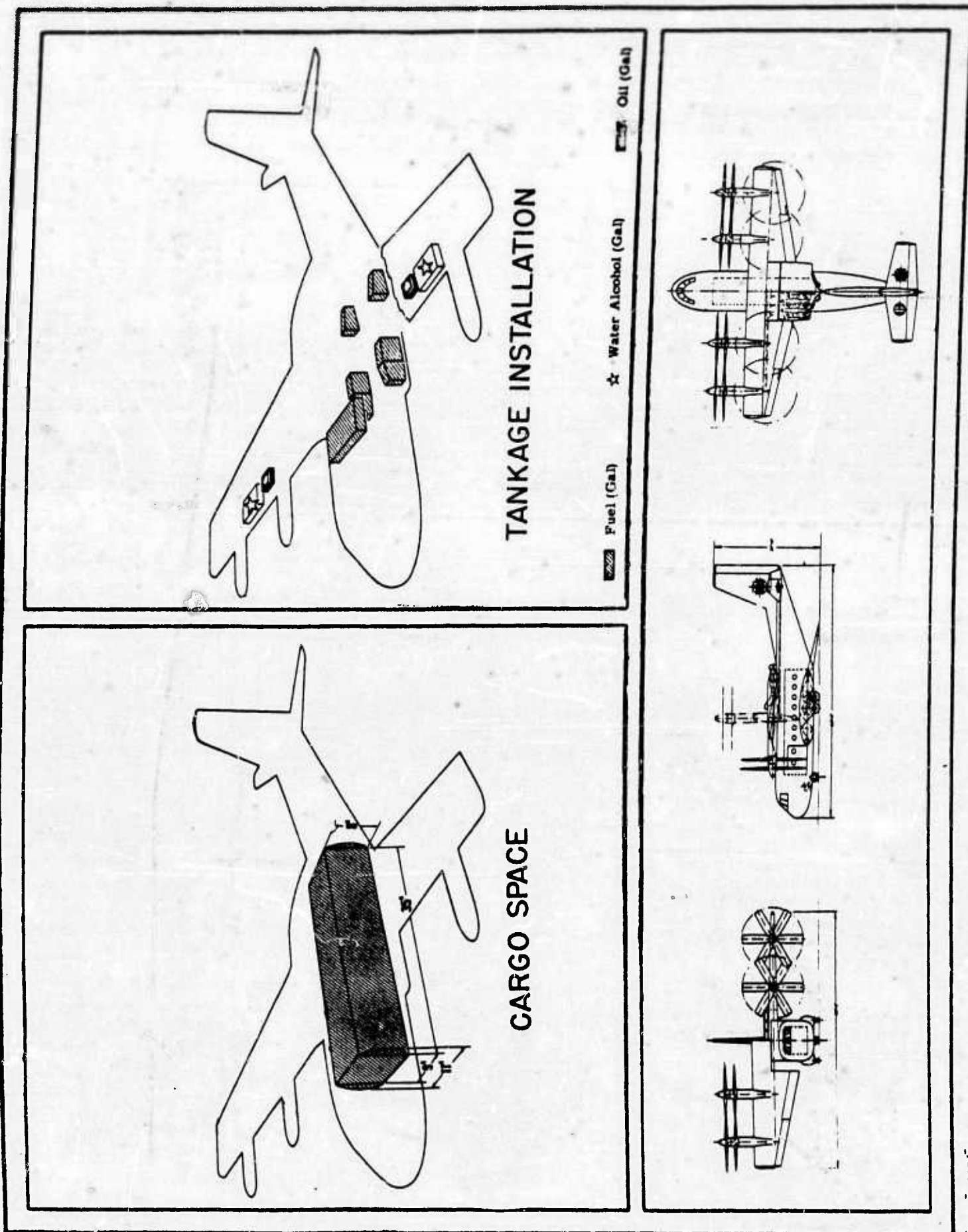
VTOL COMPARATIVE STUDY

"TILTING WING PROPELLER"

REPORT R-83

VERTOL AIRCRAFT CORP.

CONTRACT NONR 1681 (00)



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W I G H T S

This aircraft employs a wing-propeller combination which can be tilted to a vertical attitude through approximately eighty degrees to utilize the propeller thrust in hovering. The propellers are interconnected with the power plants mounted horizontally on top of the fuselage.

Pitch and yaw control in hovering and slow speed flight is provided through the use of submerged fans in the tail connected to the propeller drive system while roll control is obtained through differential thrust of the propellers.

Normal Internal	2790 Gal.	6.5 lbs./gal.
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INDEX

ELECTRONICS

UHF plus Homing
Adapter ARC-27 and ARA-25

VHF plus Homing
Adapter

Liaison - Range 1000 Miles

Interphone

POWER PLANT

No. and Model	(6) 550 B-1
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Manufacturer

Eng. Spec. No. 394-B

ENGINE RATINGS

	SHIP	RPM	ALT.
T.O.	5168	9900	S.L.
MIL.	5168	9900	S.L.
NOR.	4590	9900	S.L.

DI MENSIONI

Length	34 ft. 9 in.
Height	37 ft. 0 in.
Wing Span	85 ft. 6 in.
Wing Area	1170 sq. ft.
Wing Aspect Ratio	6.25
Wheel Tread	13 ft. 6 in.

July 1956

Tilt Wing

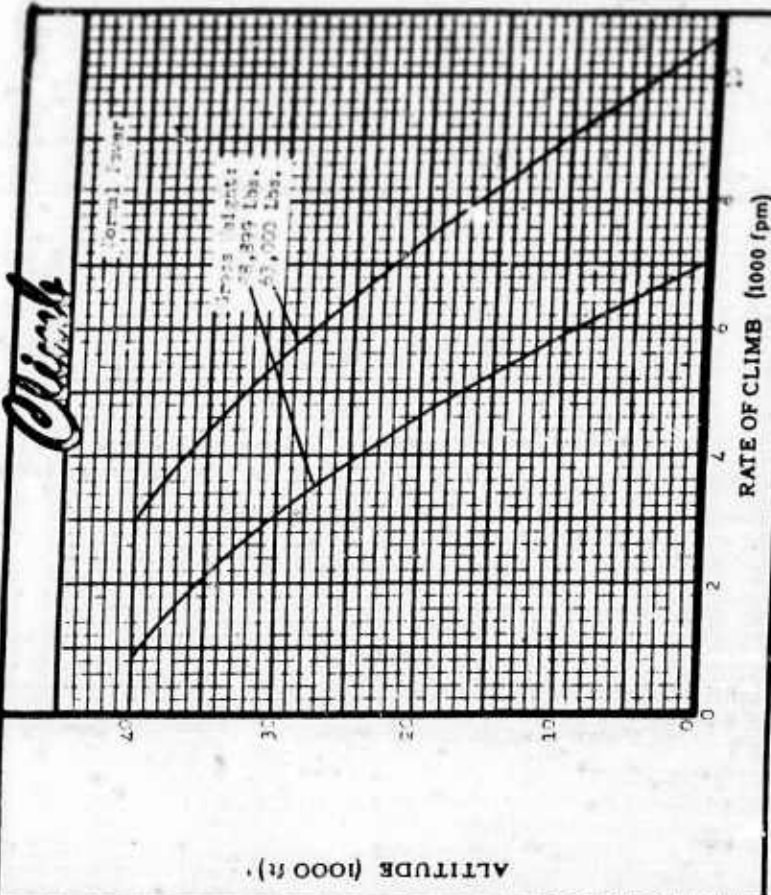
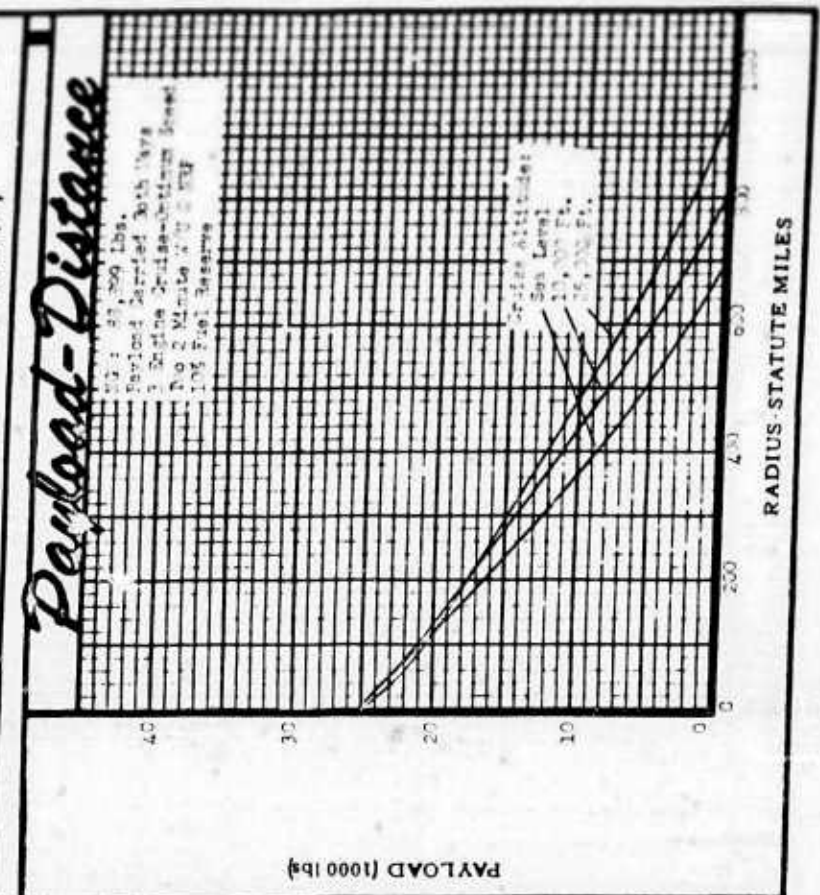
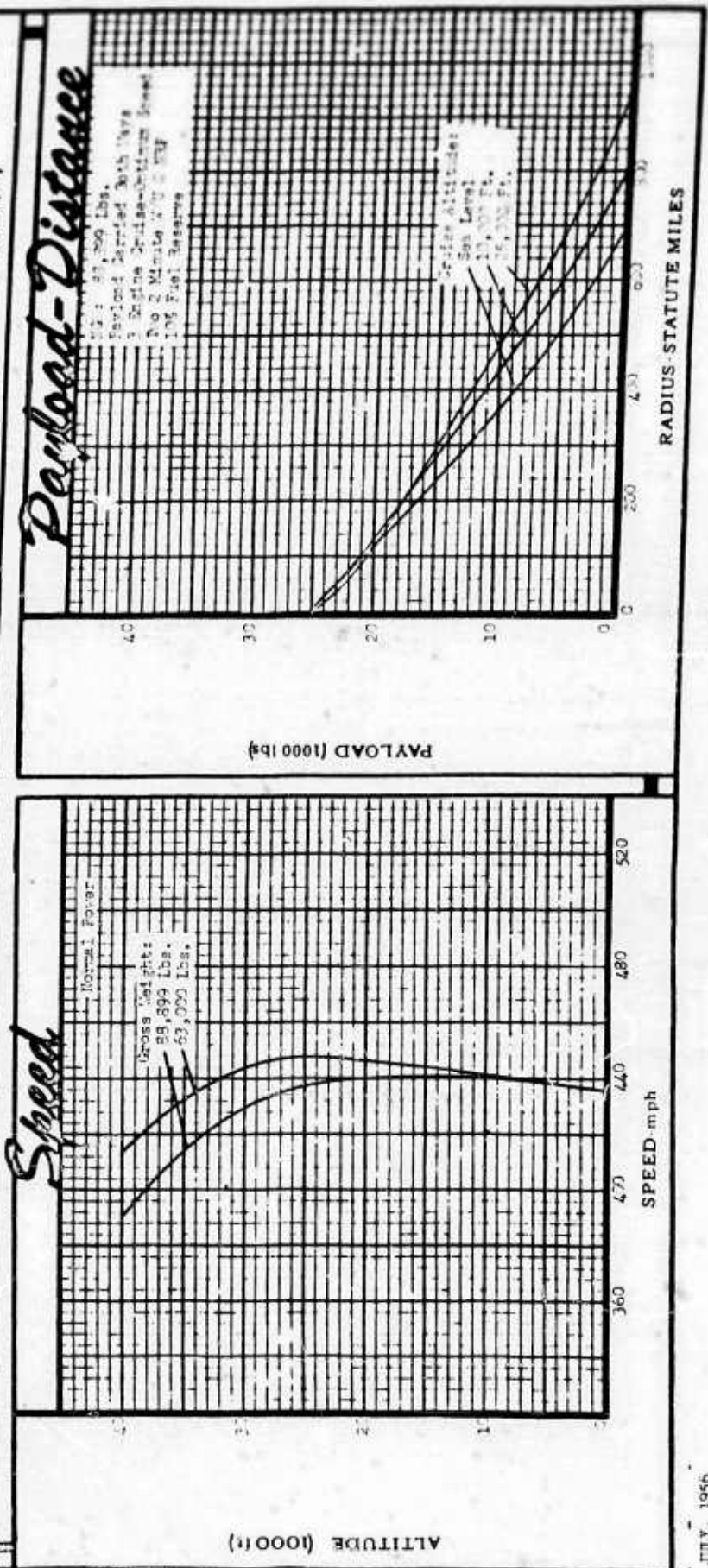
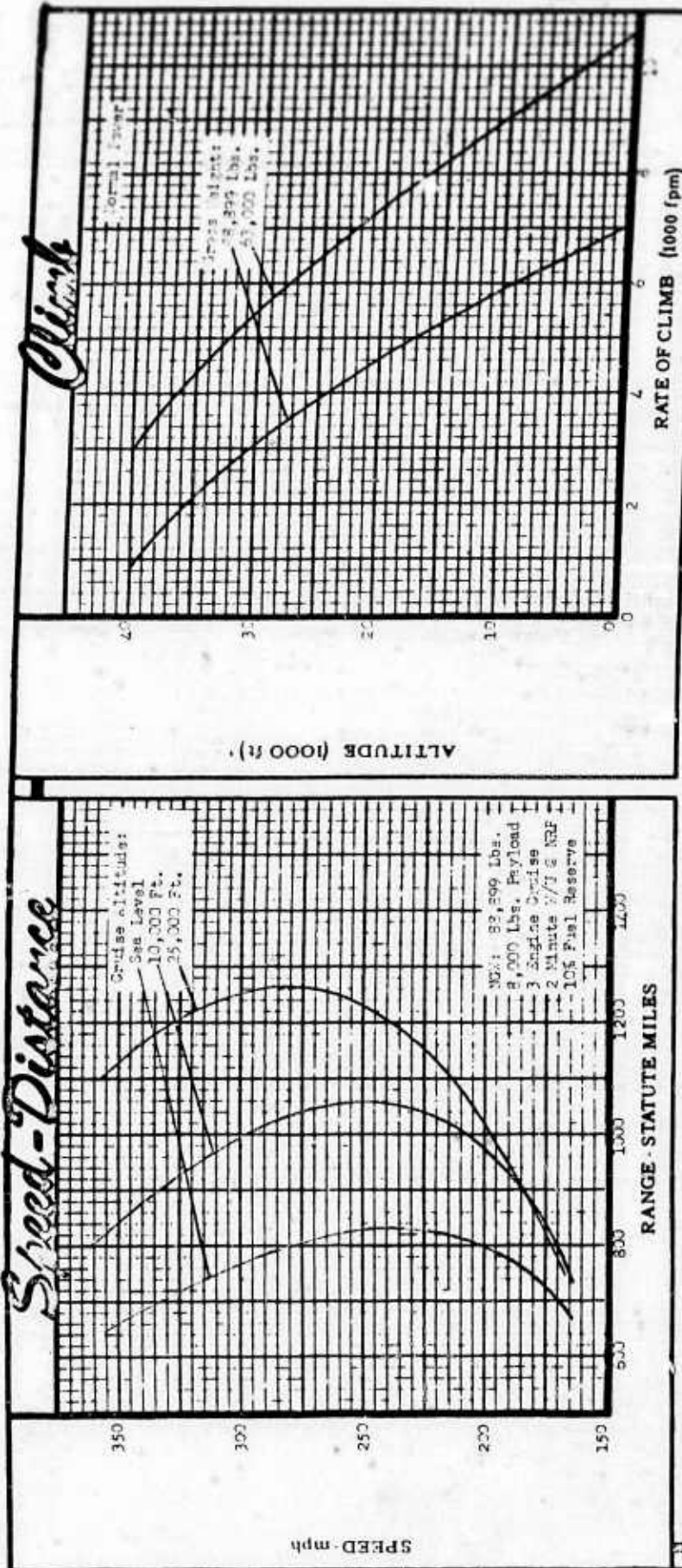
Loading and Performance - Typical Mission

C O N D I T I O N S		BASIC	FERRY RANGE
TAKE-OFF WEIGHT	(lb)	88,899	106,500
Fuel at 6.5 lb/gal	(lb)	18,120	41,160
Payload (outbound)	(lb)	8,000	0
Payload (inbound)	(lb)	4,000	0
Take-off power loading	(lb/eq ft)	2.86	3.44
Disc loading	(lb/eq ft)	64.1	77.0
Wing loading	(lb/eq ft)	75.9	91.0
Take-off ground run at 6000 ft. and 95 F/clear 50 ft.	(ft)	0/0	436
Maximum Speed at S. L.	(mph)	436	440
Maximum Speed at 10000 ft.	(mph)	440	5,750
Max. rate of climb at S. L.	(ft/min)	7,100	1.9
Time: SL to 10000 ft.	(min)	1.54	5.8
Time: SL to 25000 ft.	(min)	4.60	41,500
Service ceiling (100 fpm)	(ft)	43,000	2,830
COMBAT RADIUS OF RANGE	(n. mi)	425	300
Average Cruising Speed	(mph)	300	25,000
Cruising altitude (20% S. L.)	(ft)	10,000	69,455
FIRST LANDING WEIGHT	(lb)	81,020	48,000
Ground roll at 6000 ft. and 95 F	(ft)	0	9,700
COMBAT WEIGHT	(lb)	75,700	1.12
Cruise altitude	(ft)	10,000	3.34
Cruise speed	(mph)	300	436
Service ceiling (100 fpm)	(ft)	46,000	440
Take-off ground run at 6000 ft and 95 F/clear 50 ft	(ft)	0/0	69,455
Max. rate of climb at S. L.	(ft/min)	8,750	0
Time: SL to 10000 ft	(min)	1.98	
Time: SL to 25000 ft	(min)	4.38	
Max. speed at S. L.	(mph)	436	
Max. speed at 10000 ft.	(mph)	440	
LANDING WEIGHT	(lb)	68,680	
Ground roll at 6000 ft. and 95 F	(ft)	0	

- ① Military power
② Normal power
③ Detailed description of missions are given on Page 5
④ With 4000# return payload - no fuel added.

PERFORMANCE BASIS:

- (a) Data source: Estimated.
(b) Performance is based on powers shown on Page 3
(c) Data do not include ground effect.



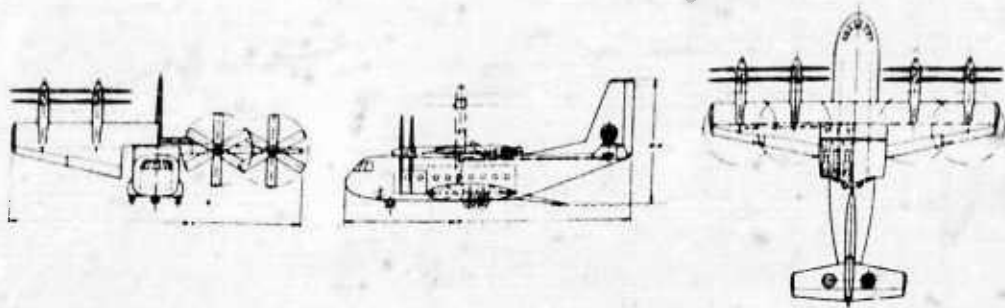
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N O T E S

- I. The design or basic mission of the aircraft is essentially that of a military transport suitable for transporting either troops or associated equipment with the additional requirement for a vertical take-off capability to increase its mobility in the absence of unprepared landing surfaces.
- II. The basic mission requirements in addition to the capability of hovering @ 6,000' and 95°F with military power consist of the following:
 1. Two minute warm-up @ normal power prior to take-off.
 2. Take-off vertically with 8,000# payload and climb on course to 10,000' with normal power.
 3. Cruise at 10,000', 80 per cent of the required radius (425 statute miles), descend to sea and cruise the remaining 20% to the destination.
 4. Hover allowance of 5 minutes @ sea level for vertical take-off and landing operation.
 5. Return cruise with 4000# payload is initially @ sea level again for 20% of the required radius followed by a normal power climb to 10,000'. Remaining cruise at 10,000' completes the 425 statute mile radius requirement.
 6. Fuel allowances include 10% for reserve with a 5% increase in manufacturer's SFC values.
- III. An additional ferry mission applicable to this aircraft consists of the following:
 1. Two minute warm-up @ normal power prior to take-off.
 2. With a 20% increase in normal gross weight take-off and climb on course with normal power to 25,000'.
 3. At 25,000' cruise out a maximum distance prior to landing with a 10% fuel reserve.
 4. Manufacturer's SFC values increased 5%.

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Characteristics Summary



AVAILABILITY			PROCUREMENT			
Number available			Number to be delivered in fiscal years			
ACTIVE	RESERVE	TOTAL				

STATUS	

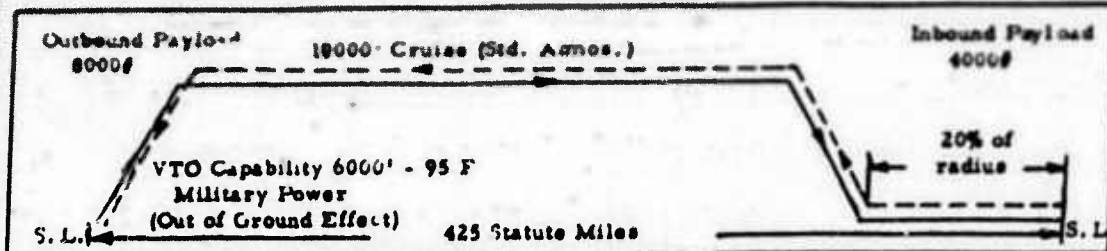
POWER PLANT	FEATURES	GENERAL																
(6) Allison 550 B-1 Turboprops Engine Ratings <table><tr><td></td><td>SHp</td><td>RPM</td><td>ALT</td></tr><tr><td>TO:</td><td>5168</td><td>9900</td><td>S.L.</td></tr><tr><td>MIL:</td><td>5168</td><td>9900</td><td>S.L.</td></tr><tr><td>NOR:</td><td>4590</td><td>9900</td><td>S.L.</td></tr></table>		SHp	RPM	ALT	TO:	5168	9900	S.L.	MIL:	5168	9900	S.L.	NOR:	4590	9900	S.L.	Rear aperture loading ramp. Cargo floor at truck bed loading height.	Crew 3 Troops 35 Cabin Floor Area 315 sq.ft. Cabin Volume 2,520 cu.ft.
	SHp	RPM	ALT															
TO:	5168	9900	S.L.															
MIL:	5168	9900	S.L.															
NOR:	4590	9900	S.L.															

JULY, 1996

TILT WING

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Characteristics Summary Basic Mission



PERFORMANCE		
COMBAT RADIUS	FERRY RANGE	S P E E D
425 Stat. Mi. with 8000 lb payload at 300 mph avg.	1265 Stat. Mi. with 2790 gal. fuel at 280 mph avg. at 88,899 lb T.O. wt. and 8000 lbs payload	MAX 436 mph at Sea Level ft alt, N.R.P. MAX 440 mph at 10,000 ft alt, N.R.P.
CLIMB	C E I L I N G	T A K E - O F F
7100 fpm sea level, take-off weight normal power	43000 ft 100 fpm, take-off weight normal power	Vertical Take-Off
5900 fpm 10000 ft take-off weight normal power		
L O A D	W E I G H T S	H O V E R I N G C E I L.
Crew 600 lbs Payload 8000 lbs Fuel 18120 lbs Oil 300 lbs	Useful 28862 lb Empty 60037 lb Take-Off 88,899 lb	6000 ft., take-off Military Power 98°F Ambient Temperature

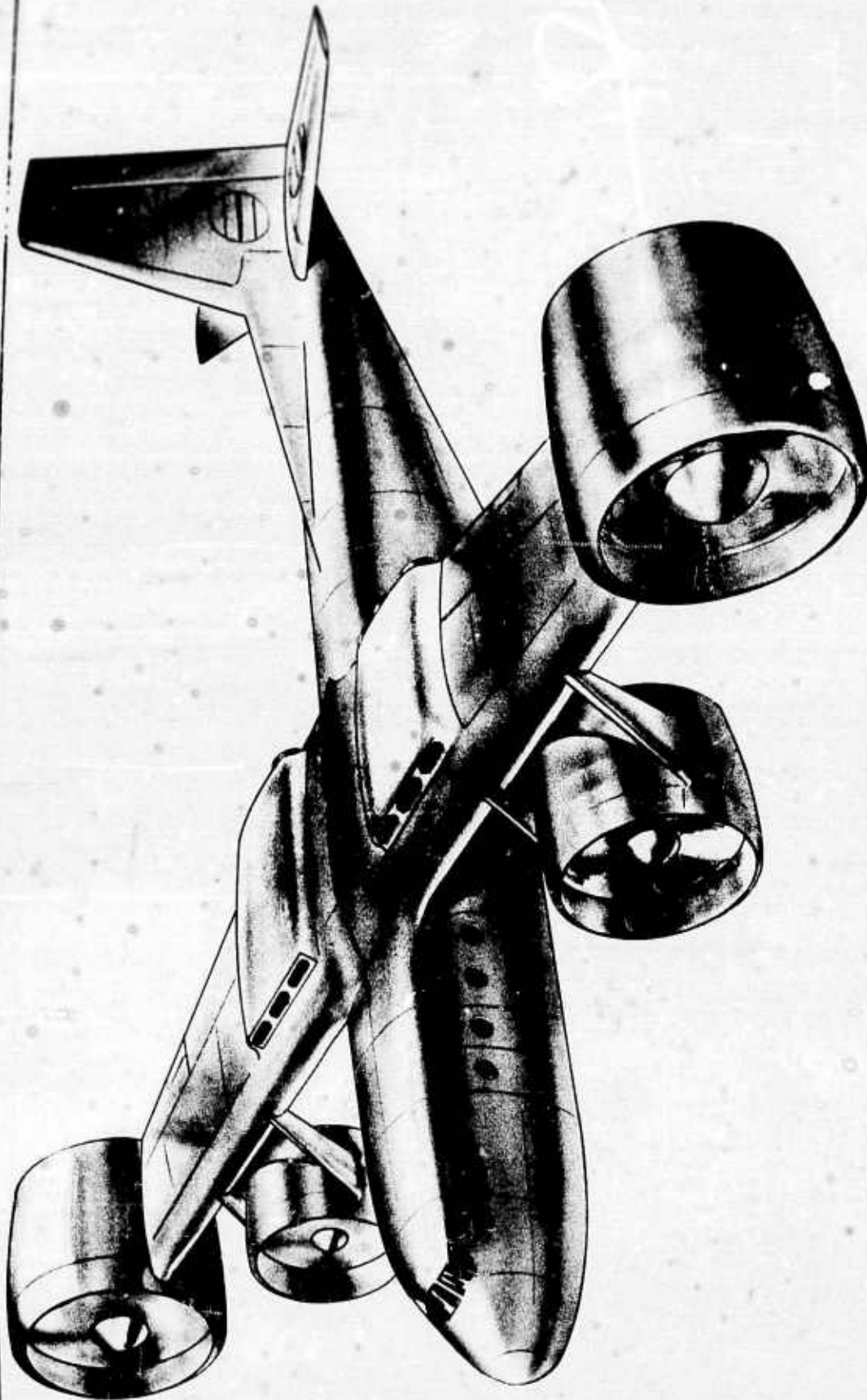
N O T E S

1. Performance Basis:
 - (a) Data Source: Estimated
 - (b) Performance is Based on Powers Shown on Page 3
 - (c) Data do not include Ground Effect

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Report R-83



Standard Aircraft Characteristics

VTOL COMPARATIVE STUDY

"TILTING DUCTED PROPELLER"

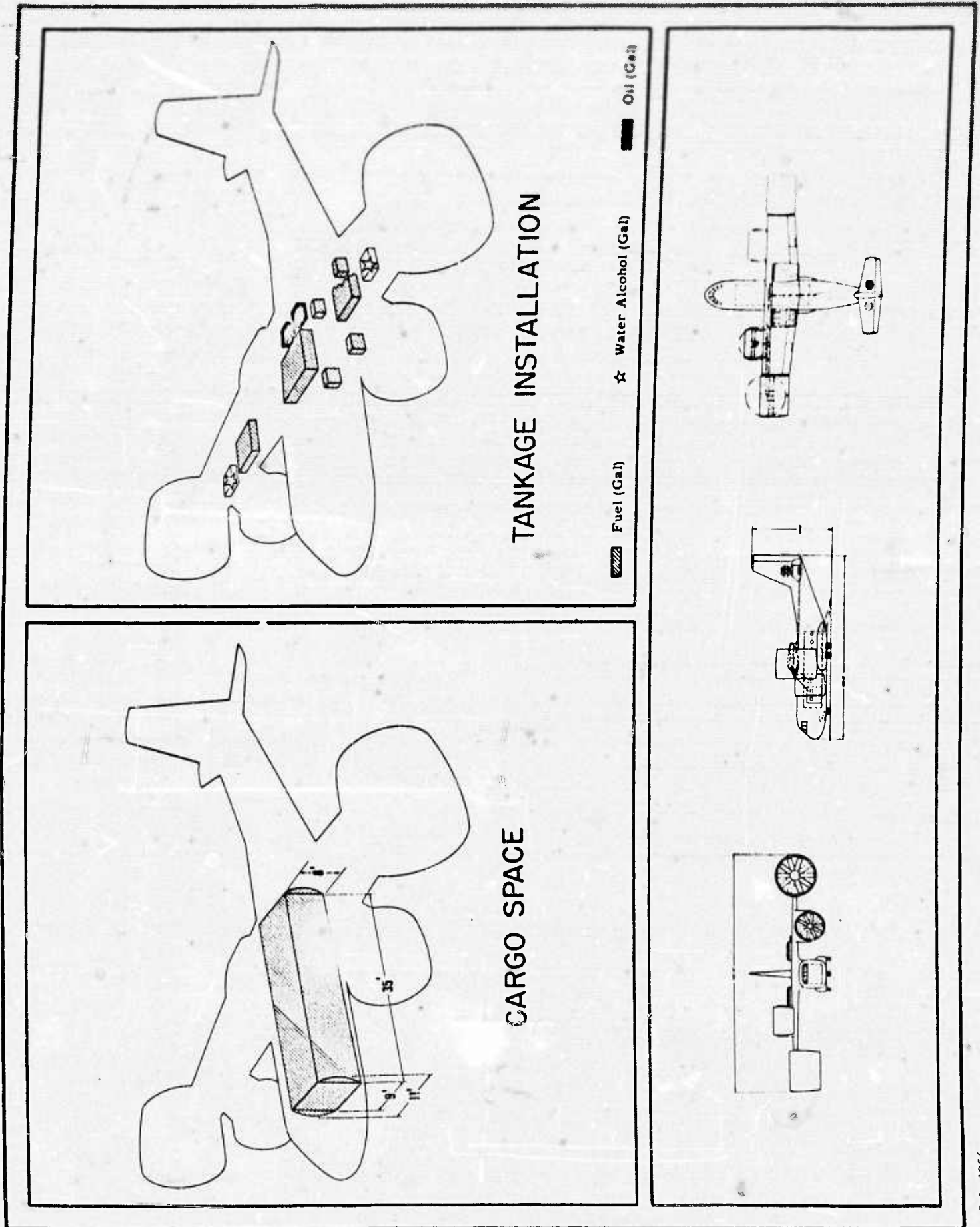
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POWER PLANT		Mission and Description The basic mission given in detail in the notes is to provide air transportation for troops and cargo with specific requirements for VTOL operation and a radius capability of 425 statute miles. This aircraft employs four ducted fans mounted on the wing which can be rotated through ninety degrees to provide thrust in both the hovering and forward flight condition. The fans are interconnected with the power plants located on the inboard section of the wing. Pitch and yaw control obtained from submerged fans in the tail surfaces driven by shafting from the interconnected propeller system. Roll control is obtained through differential propeller thrust.	W E I G H T S	
No. and Model	(6) 550 B-1		Normal Gross Wt. VTOL - 6000' @ 95°F 93,270 lb	
Manufacturer	Allison		Weight Empty 62,860 lb.	
ENGINE RATINGS		F U E L Normal Internal 3030 Gal. 6.5 lbs./gal.	ELECTRONICS UHF plus Homing Adapter ARC-27 and ARA-25 VHF plus Homing Adapter ARC Type 12 and ARA 8A Liaison - Range 1000 Miles Interphone	
SHP	RPM			ALT.
T. O.	5168			9900 S. L.
MIL.	5168	9900 S. L.		
NOR.	4590	9900 S. L.		
DIMENSIONS		MISCELLANEOUS		
Length	84 ft. 9 in.			
Height	37 ft. 0 in.			
Wing Span	109 ft. 0 in.			
Wing Area	1426 ft. ² (includes 50% ducts)			
Wing Aspect Ratio	8.35			
Wheel Tread	14 ft. 0 in.			

Tilting Ducted Propellers

CONFIDENTIAL

Loading and Performance — Typical Mission

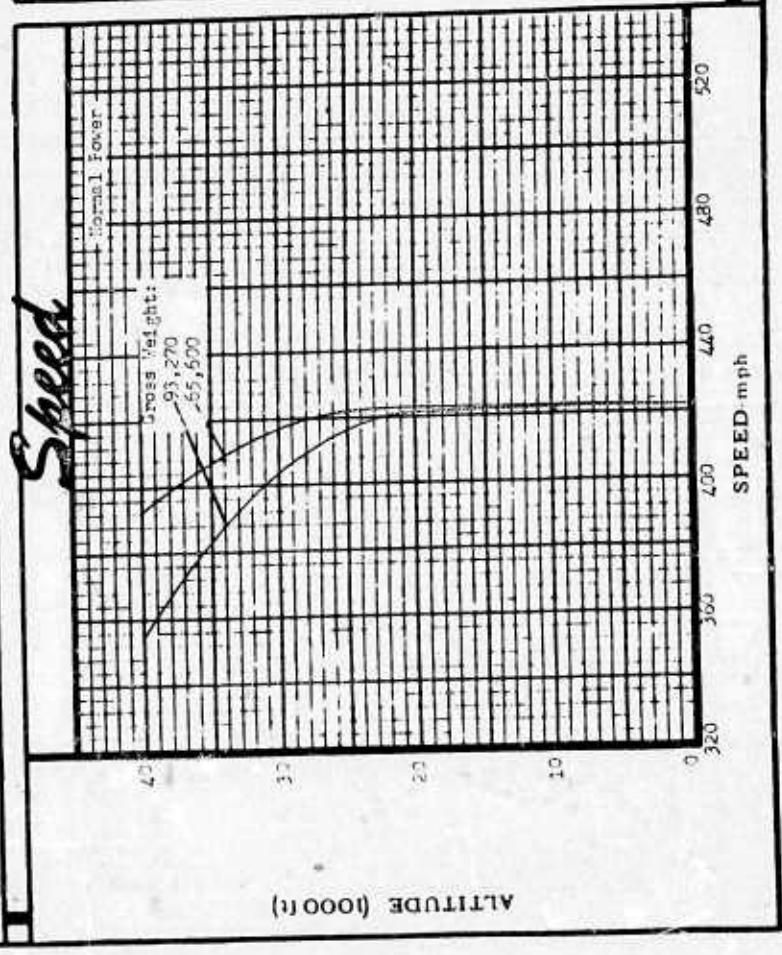
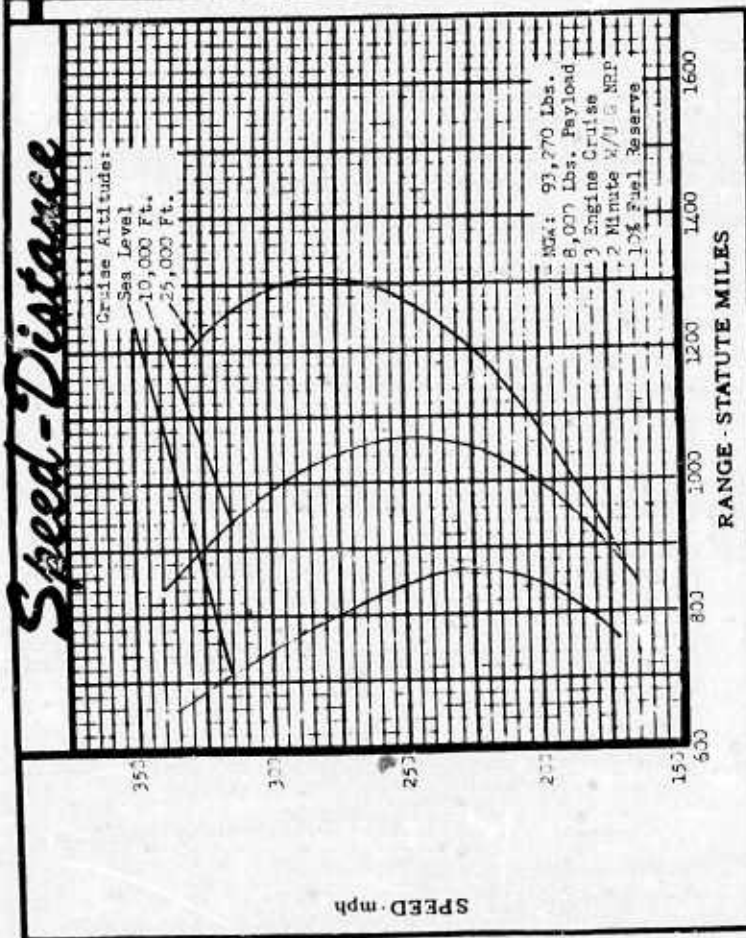
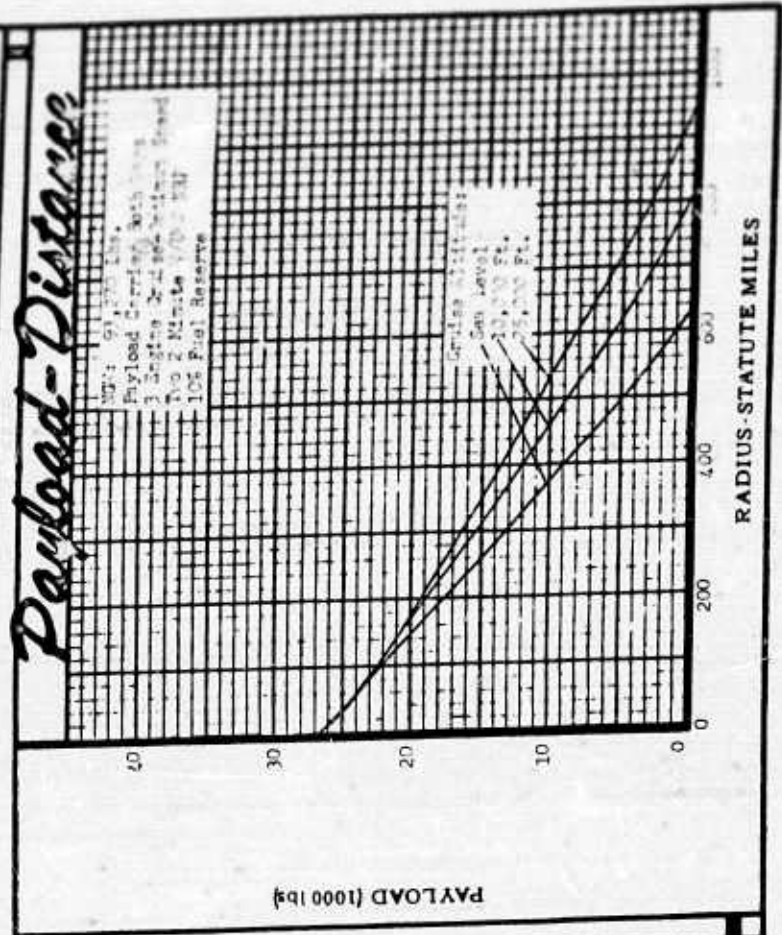
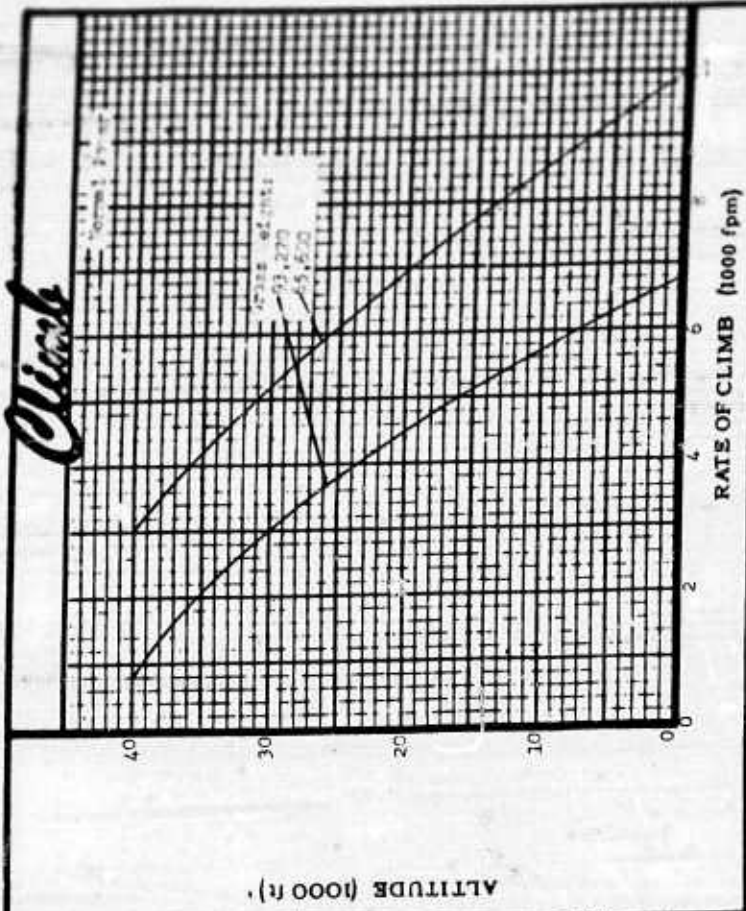
C O N D I T I O N S		BASIC	FERRY RANGE
TAKE-OFF WEIGHT		93,270 (lb)	111,924 (lb)
Fuel at 6.5 lb/gal		19,690 (lb)	46,479 (lb)
Payload (outbound)		8,000 (lb)	0 (lb)
Take-off power loading		3.01 (lb/Shop)	3.61 (lb/Shop)
Disc loading		131.5 (lb/sq ft)	158 (lb/sq ft)
Wing loading		65.5 (lb/sq ft)	78.5 (lb/sq ft)
Take-off ground run at 6000 ft. and 95 F/clear 50 ft.		0/0 (ft)	424 (ft)
Maximum Speed at S. L.		424 (mph)	424 (mph)
Maximum Speed at 10000 ft.		424 (mph)	5,200 (mph)
Max. rate of climb at S. L.		1.63 (ft/min)	2.12 (ft/min)
Time: SL to 10000 ft.		4.86 (min)	6.64 (min)
Time: SL to 25000 ft.		42,200 (ft)	36,800 (ft)
Service ceiling (100 fpm)		425 (ft)	2,857 (ft)
COMBAT RADIUS		300 (mi)	300 (mi)
Average Cruising Speed		10,000 (ft)	10,000 (ft)
Cruising altitude (20% @ S. L.)		85,060 (ft)	25,000 (ft)
FIRST LANDING WEIGHT		0 (lb)	0 (lb)
Ground roll at 6000 ft. and 95 F		79,740 (ft)	71,893 (ft)
COMBAT WEIGHT		10,000 (ft)	51,000 (ft)
Cruise altitude		46,000 (ft)	0 (ft)
Cruise speed		0/0 (ft)	8,100 (ft)
Service ceiling (100 fpm)		1.33 (min)	1.18 (min)
Take-off ground run at 6000 ft and 95 F/clear 50 ft		3.89 (min)	3.48 (min)
Max. rate of climb at S. L.		424 (ft/min)	424 (ft/min)
Time: SL to 10000 ft		424 (ft)	424 (ft)
Time: SL to 25000 ft		71,900 (ft)	71,893 (ft)
Max. speed at S. L.		0 (ft)	0 (ft)
Max. speed at 10000 ft.		0 (ft)	0 (ft)
LANDING WEIGHT		0 (ft)	0 (ft)
Ground roll at 6000 ft. and 95 F		0 (ft)	0 (ft)

PERFORMANCE BASIS:
(a) Data source: Estimated
(b) Performance is based on powers shown on Page 3
(c) Data do not include ground effect.

1 Military power
2 Normal power
3 Detailed description of missions are given on Page 6
4 With 4000# return payload - no fuel added.

Tilting Ducted Propellers

CONFIDENTIAL

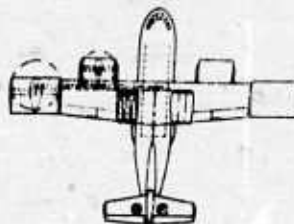
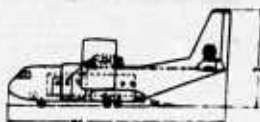


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NOTES

- I. The design or basic mission of the aircraft is essentially that of a military transport suitable for transporting either troops or associated equipment with the additional requirement for a vertical take-off capability to increase its mobility in the absence of unprepared landing surfaces.
- II. The basic mission requirements in addition to the capability of hovering @ 6,000' and 95°F with military power consist of the following:
 1. Two minute warm-up @ normal power prior to take-off.
 2. Take-off vertically with 8,000# payload and climb on course to 10,000' with normal power.
 3. Cruise at 10,000', 80 per cent of the required radius (425 statute miles), descend to sea and cruise the remaining 20% to the destination.
 4. Hover allowance of 5 minutes @ sea level for vertical take-off and landing operation.
 5. Return cruise with 4000# payload is initially @ sea level again for 20% of the required radius followed by a normal power climb to 10,000'. Remaining cruise at 10,000' completes the 425 statute mile radius requirement.
 6. Fuel allowances include 10% for reserve with a 5% increase in manufacturer's SFC values.
- III. An additional ferry mission applicable to this aircraft consists of the following:
 1. Two minute warm-up @ normal power prior to take-off.
 2. With a 20% increase in normal gross weight take-off and climb on course with normal power to 25,000'.
 3. At 25,000' cruise out a maximum distance prior to landing with a 10% fuel reserve.
 4. Manufacturer's SFC values increased 5%.

Characteristics Summary



AVAILABILITY			PROCUREMENT			
Number available			Number to be delivered in fiscal years			
ACTIVE	RESERVE	TOTAL				

STATUS

POWER PLANT	FEATURES	GENERAL																
(6) Allison 550 B-1 Turboprops Engine Ratings <table><tr><td></td><td>SHP</td><td>RPM</td><td>ALT</td></tr><tr><td>TO:</td><td>5168</td><td>9900</td><td>S.L.</td></tr><tr><td>MIL:</td><td>5168</td><td>9900</td><td>S.L.</td></tr><tr><td>WCR:</td><td>4590</td><td>9900</td><td>S.L.</td></tr></table>		SHP	RPM	ALT	TO:	5168	9900	S.L.	MIL:	5168	9900	S.L.	WCR:	4590	9900	S.L.	Rear aperture loading ramp. Cargo floor at truck bed loading height.	Crew 3 Troops 35 Cabin Floor Area 315 sq.ft Cabin Volume 2,520 cu.ft
	SHP	RPM	ALT															
TO:	5168	9900	S.L.															
MIL:	5168	9900	S.L.															
WCR:	4590	9900	S.L.															

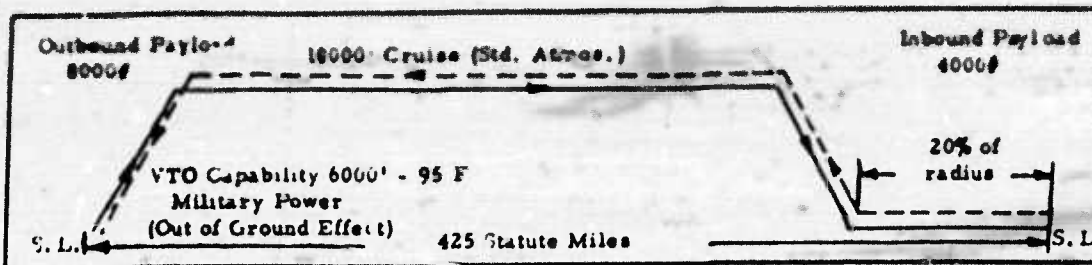
JULY, 1996

TILTING DUCTED PROPELLER

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Characteristics Summary Basic Mission



PERFORMANCE		
COMBAT RADIUS	FERRY RANGE	S P E E D
425 Stat. Mi. with 8000 lb payload at 300 mph avg.	1310 Stat. Mi. with 3030 gal. fuel at 280 mph avg. at 93270 lb T.O. wt. and 8000 lbs. payload	MAX 424 mph at Sea Level ft alt, N.R.P. MAX 424 mph at 10,000 ft alt, N.R.P.
C L I M B	C E I L I N G	T A K E - O F F
6660 fpm sea level, take-off weight normal power	42,200 ft 100 fpm, take-off weight normal power	Vertical Take-Off
5600 fpm 10000 ft take-off weight normal power		
L O A D	W E I G H T S	H O V E R I N G C E I L.
Crew 600 lbs Payload 8000 lbs Fuel 19690 lbs Oil 300 lbs	Useful 30410 lb Empty 62860 lb Take-Off 93270 lb	6000 ft., take-off Military Power 95° Ambient Temperature

NOTES

1. Performance Basis:
 - (a) Data Source: Estimated
 - (b) Performance is Based on Powers Shown on Page 3
 - (c) Data do not include Ground Effect

July 1956

Tilting-Ducted Propeller

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Standard Aircraft Characteristics

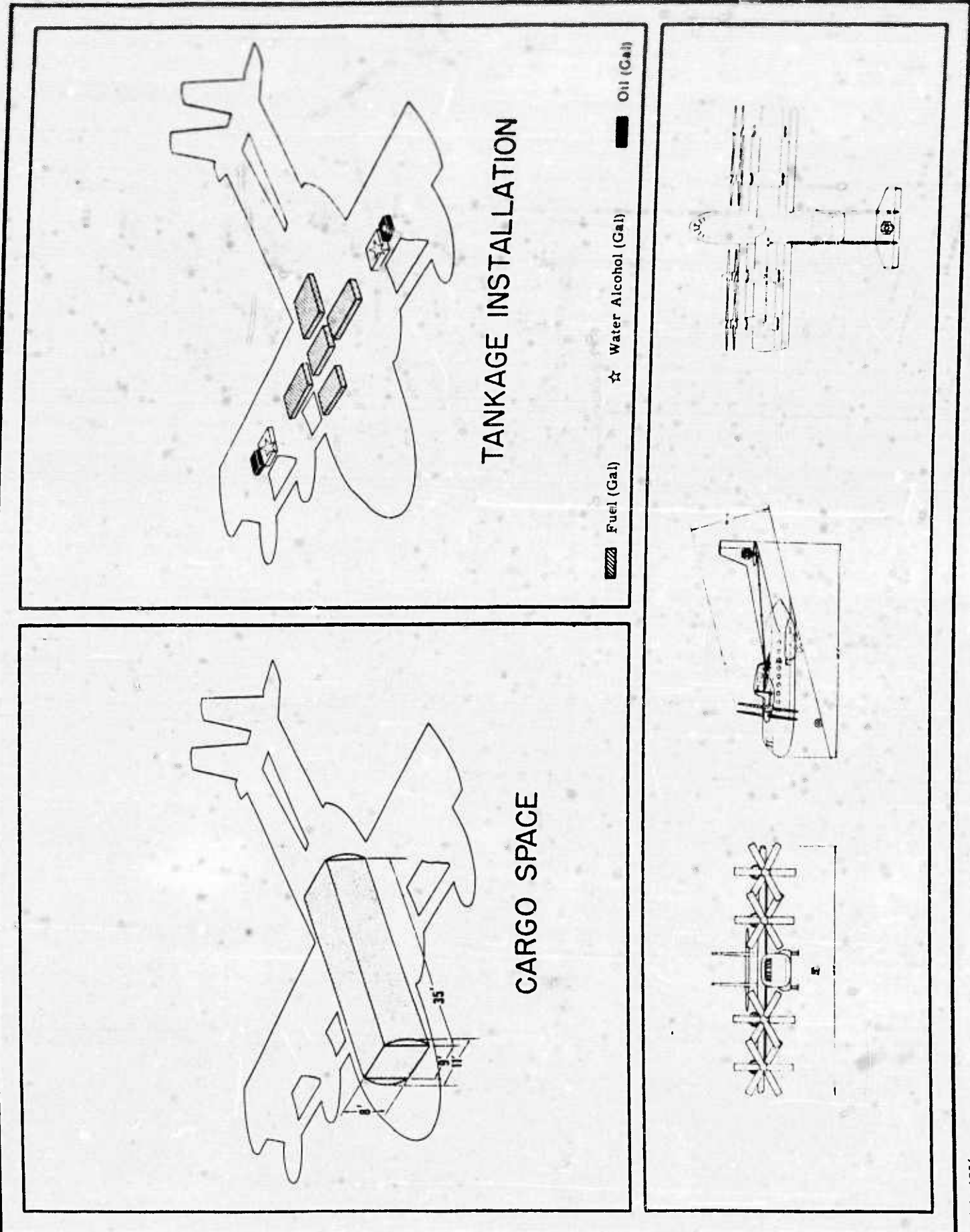
VTOL COMPARATIVE STUDY

"VECTORED LIFT"

REPORT R-83

VERTOL AIRCRAFT CORP.

CONTRACT NONR 1681(00)



POWER PLANT		Mission and Description		WEIGHTS
No. and Model	(8) 550 B-1	The basic mission given in detail in the notes is to provide air transportation for troops and cargo with specific requirements for VTOL operation and a radius capability of 425 statute miles. The vectored lift configuration derives its VTOL capabilities by deflecting the propeller slipstream through large angles by means of a full-span double-flap arrangement. The propellers are interconnected with two power plants located in each of the four nacelles. The use of a controllable forward located stabilizer immersed in the propeller slipstream alleviates hovering pitching moments. Additional pitch control as well as yaw control are obtained through submerged fans in the tail surfaces and driven by the central propeller drive system.		Normal Gross Wt. VTOL - 6000' @ 95°P = 111,313 lb.
Manufacturer	Allison			Weight Empty = 78,663 lb.
Eng. Spec No.	394-B			
ENGINE RATINGS		FUEL		
T.O.	SHP 5168 RPM 9900 ALT. S.L.	Normal Internal 3280 Gal. 6.5 lbs./gal.		
MIL.	5168 9900 S.L.			
NOR.	4590 9900 S.L.			
DIMENSIONS		ELECTRONICS		
Length	84 ft. 6 in.	UHF plus Homing Adapter ARC-27 and ARA-25		
Height	32 ft. 0 in.	VHF plus Homing Adapter ARC Type 12 and ARA 8A		
Wing Span	98 ft. 6 in.	Liaison - Range 1000 Miles		
Wing Area	1430	Interphone		
Wing Aspect Ratio	6.79			
Wheel Tread	13 ft. 6 in.			
		MISCELLANEOUS		

July 1956

Vectored Lift

CONFIDENTIAL

Loading and Performance - Typical Mission

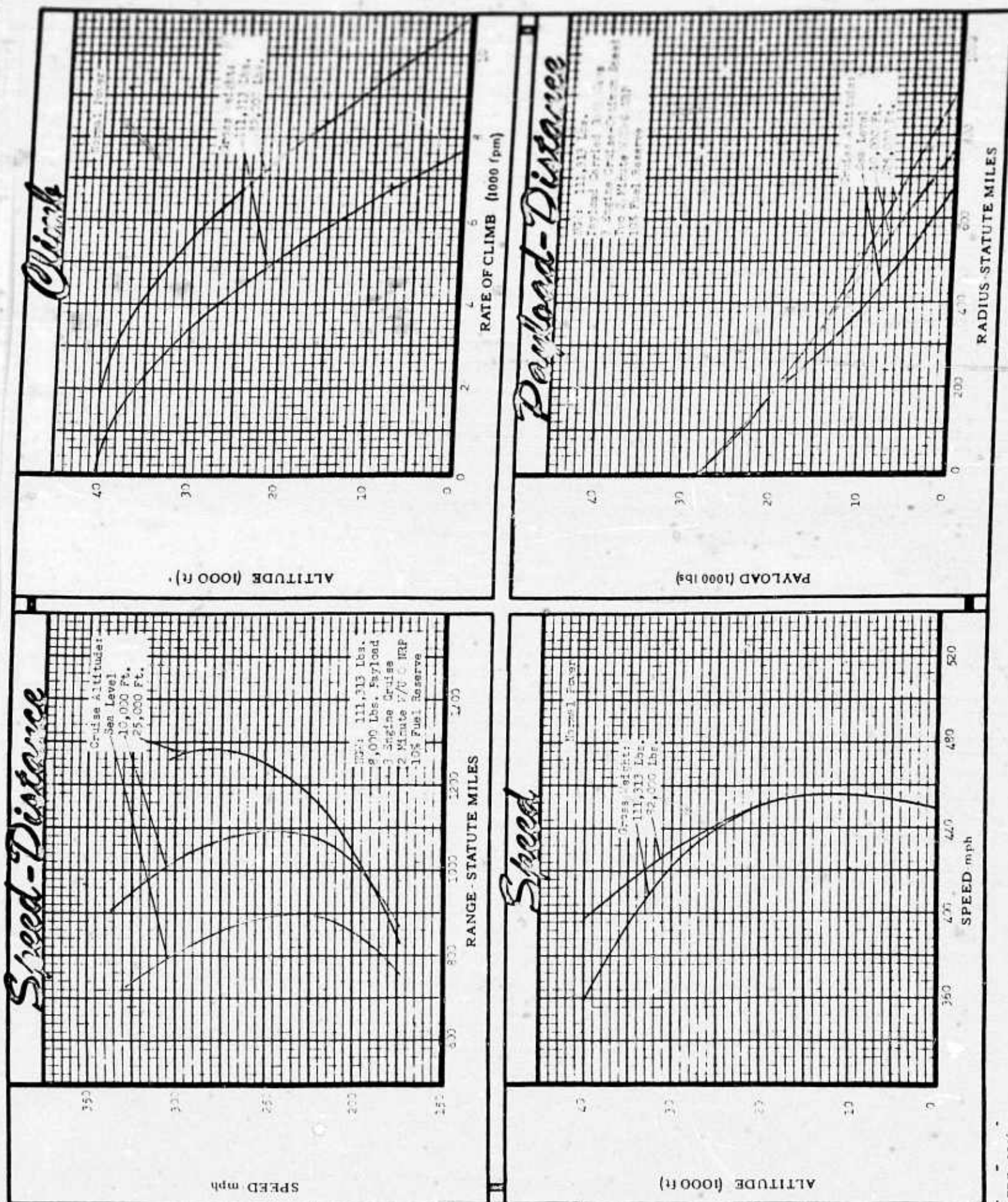
C O N D I T I O N S	BASIC	FERRY RANGE
TAKE-OFF WEIGHT	111,313	133,500
Fuel at 6.5 lb/gal	21,320	48,487
Payload (outbound)	8,000	0
Payload (inbound)	4,000	0
Take-off power loading	2.69	3.23
Disc loading	57.6	69.2
Wing loading	78.0	93.4
Take-off ground run at 6000 ft. and 95 F/clear 50 ft.	0/0	450
Maximum Speed at S.L.	455	455
Maximum Speed at 10000 ft.	7,600	6,100
Max. rate of climb at S.L.	1.43	1.8
Time: SL to 10000 ft.	4.21	5.64
Time: SL to 25000 ft.	39,800	37,200
Service ceiling (100 fpm)	425	2,800
COMBAT RADIUS	300	318
Average Cruising Speed	10,000	25,000
Cruising altitude (20% @ S.L.)	101,928	
FIRST LANDING WEIGHT	0	
Ground roll at 6000 ft. and 95 F		
COMBAT WEIGHT	100,158	89,863
Cruise altitude	30,000	
Cruise speed	300	
Service ceiling (100 fpm)	41,000	42,400
Take-off ground run at 6000 ft and 95 F/clear 50 ft	0/0	
Max. rate of climb at S.L.	8,700	10,000
Time: SL to 10000 ft	1.22	1.075
Time: SL to 25000 ft	3.62	3.21
Max. speed at S.L.	450	450
Max. speed at 10000 ft.	455	455
LANDING WEIGHT	87,933	89,863
Ground roll at 6000 ft. and 95 F	0	0

NOTES

- 1 Military power
- 2 Normal power
- 3 Detailed description of missions are given on Page 6
- 4 With 4000# return payload - no fuel added.

PERFORMANCE BASIS:

- (a) Data source: Estimated
- (b) Performance is based on powers shown on Page 3
- (c) Data do not include ground effect.



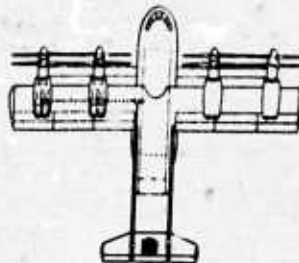
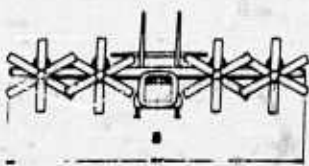
CONFIDENTIAL

N O T E S

- I. The design or basic mission of the aircraft is essentially that of a military transport suitable for transporting either troops or associated equipment with the additional requirement for a vertical take-off capability to increase its mobility in the absence of unprepared landing surfaces.
- II. The basic mission requirements in addition to the capability of hovering @ 6,000' and 95°F with military power consist of the following:
 1. Two minute warm-up @ normal power prior to take-off.
 2. Take-off vertically with 8,000# payload and climb on course to 10,000' with normal power.
 3. Cruise at 10,000', 80 per cent of the required radius (425 statute miles), descend to sea and cruise the remaining 20% to the destination.
 4. Hover allowance of 5 minutes @ sea level for vertical take-off and landing operation.
 5. Return cruise with 4000# payload is initially @ sea level again for 20% of the required radius followed by a normal power climb to 10,000'. Remaining cruise at 10,000' completes the 425 statute mile radius requirement.
 6. Fuel allowances include 10% for reserve with a 5% increase in manufacturer's SFC values.
- III. An additional ferry mission applicable to this aircraft consists of the following:
 1. Two minute warm-up @ normal power prior to take-off.
 2. With a 20% increase in normal gross weight take-off and climb on course with normal power to 25,000'.
 3. At 25,000' cruise out a maximum distance prior to landing with a 10% fuel reserve.
 4. Manufacturer's SFC values increased 5%.

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Characteristics Summary



AVAILABILITY			PROCUREMENT			
Number available			Number to be delivered in fiscal years			
ACTIVE	RESERVE	TOTAL				

STATUS

POWER PLANT	FEATURES	GENERAL																
(8) Allison 550 B-1 Turboprops Engine Ratings <table><tr><td></td><td>SHP</td><td>RPM</td><td>ALT</td></tr><tr><td>TO:</td><td>5168</td><td>9900</td><td>S.L.</td></tr><tr><td>MIL:</td><td>5168</td><td>9900</td><td>S.L.</td></tr><tr><td>WOT:</td><td>4590</td><td>9900</td><td>S.L.</td></tr></table>		SHP	RPM	ALT	TO:	5168	9900	S.L.	MIL:	5168	9900	S.L.	WOT:	4590	9900	S.L.	Rear aperture loading ramp. Cargo floor at truck bed loading height.	Crew 3 Troops 35 Cabin Floor Area 315 sq.ft. Cabin Volume 2,520 cu.ft.
	SHP	RPM	ALT															
TO:	5168	9900	S.L.															
MIL:	5168	9900	S.L.															
WOT:	4590	9900	S.L.															

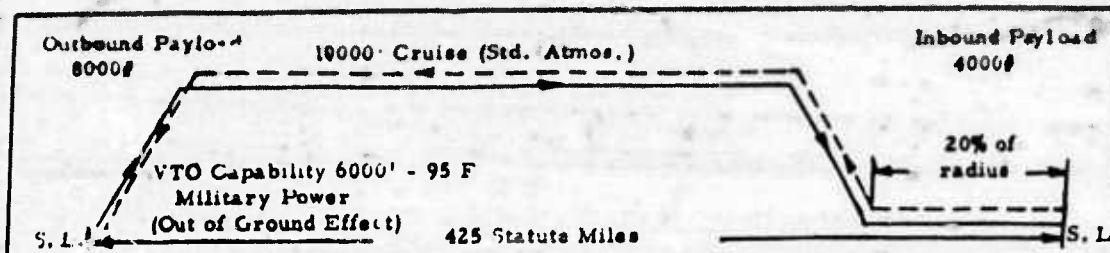
JULY, 1996

VECTORED LIFT

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Characteristics Summary Basic Mission



PERFORMANCE

COMBAT RADIUS	FERRY RANGE	S P E E D
425 Stat. Mi. with 8000 lb payload at 300 mph avg.	1280 Stat. Mi. with 3280 gal. fuel at 280 mph avg. at 111,313 lb T.O. wt. and 8000 lbs payload	MAX 450 mph at Sea Level ft alt, N.R.P. MAX 455 mph at 10,000 ft alt, N.R.P.
C L I M B	C E I L I N G	T A K E - O F F
7600 fpm sea level, take-off weight normal power	39800 ft 100 fpm, take-off weight normal power	Vertical Take-Off
6400 fpm 10000 ft take-off weight normal power		
L O A D	W E I G H T S	H O V E R I N G C E I L.
Crew 600 lbs Payload 8000 lbs Fuel 21320 lbs Oil 400 lbs	Useful 32450 lb Empty 78863 lb Take-Off 111,313 lb	6000 ft., take-off Military Power 95° Ambient Temperature

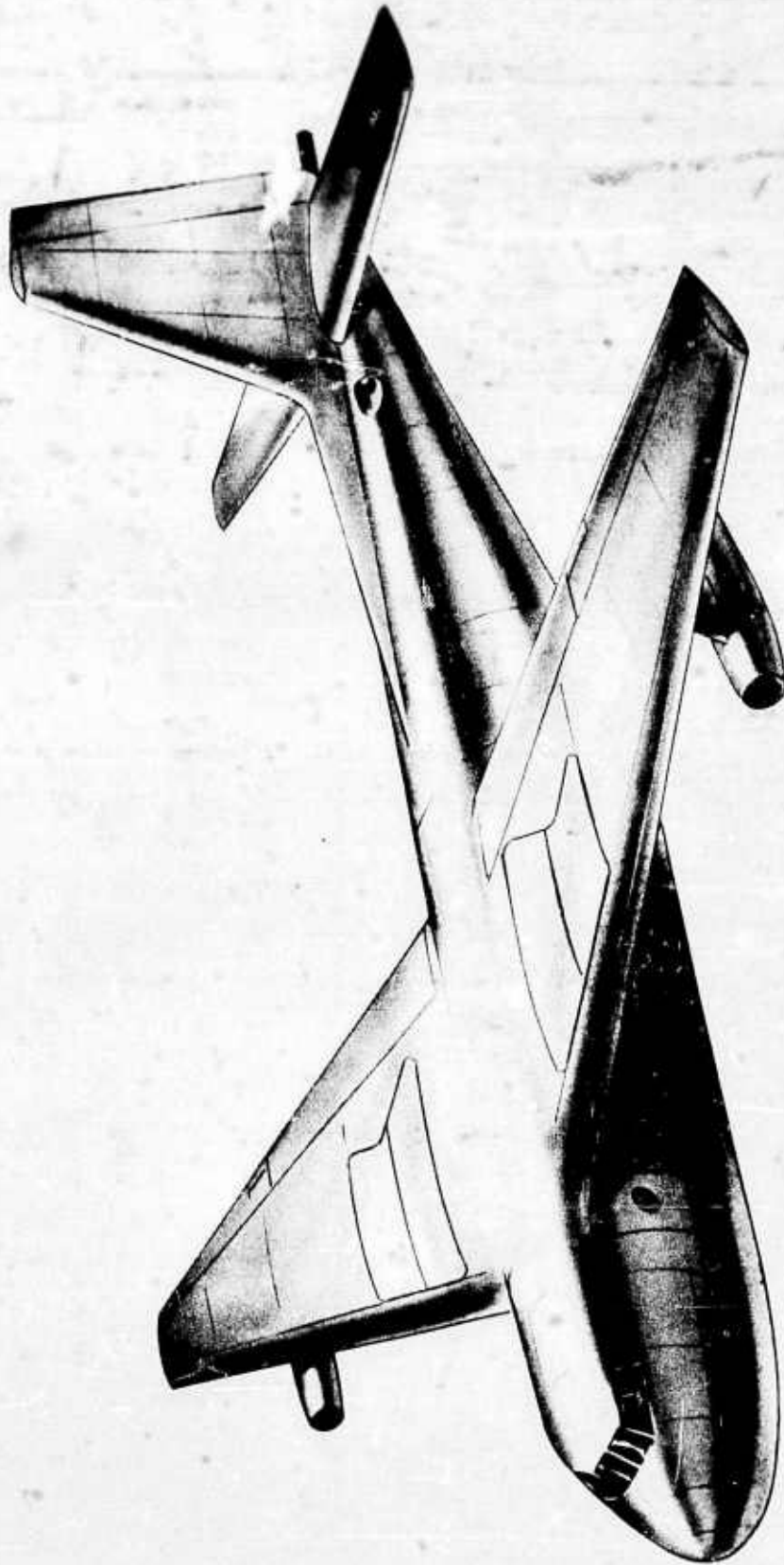
N O T E S

1. Performance Basis:
 - (a) Data Source: Estimated
 - (b) Performance is Based on Powers Shown on Page 3
 - (c) Data do not include Ground Effect

July 1956

Vectored Lift

CONFIDENTIAL



Standard Aircraft Characteristics

VTOL COMPARATIVE STUDY

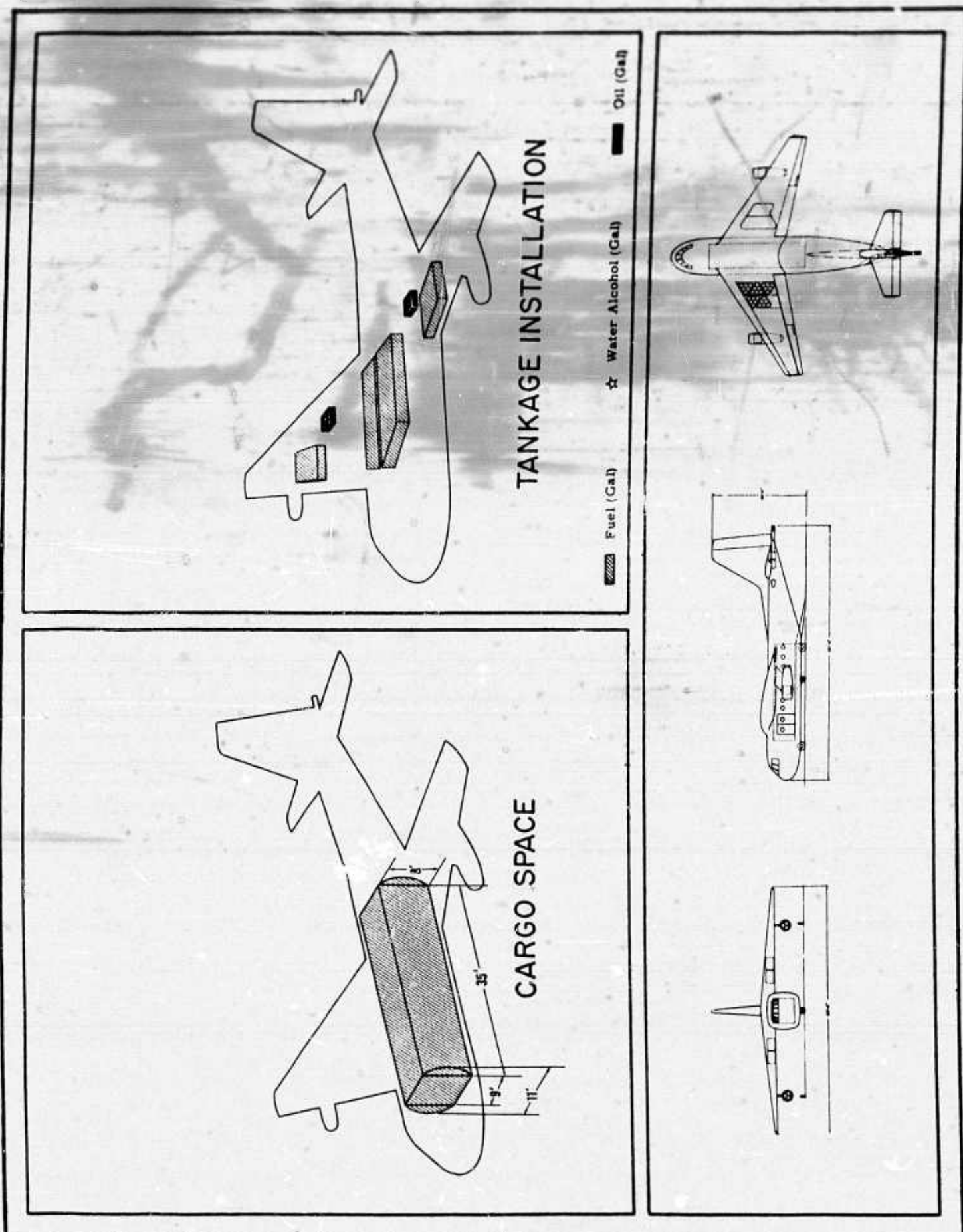
"SPECIAL HOVERING TURBOJET"

REPORT R-83

VERTOL AIRCRAFT CORP.

CONTRACT NoNR 1681(00)

CONFIDENTIAL



July 1956

Special Hovering Turbojet

CONFIDENTIAL

POWER PLANT		Mission and Description		WEIGHTS	
No. and Model	(68) J-85	The basic mission given in detail in the notes is to provide air transportation for troops and cargo with specific requirements for VTOL operation and a radius capability of 425 statute miles. The special hovering turbojet derives its vertical capabilities from 10 clusters of six modified J-85 turbojets mounted vertically in the inboard wing area. For forward thrust three J-85 engines are installed in pods suspended on each wing. In addition two J-85's are located in the tail for pitch and yaw control and in addition may be used for forward propulsion. Roll control is obtained by bleeding air from the six engines located in the wing pods.		Normal Gross Wt. VTOL - 60000 lbs. 95°F = 107,246 lb.	
Manufacturer	General Electric			Weight Empty = 51,506 lb.	
Eng. Spec No.	R55SE5				
ENGINE RATINGS				FUEL	
STATIC THRUST	ALT.			Normal Internal	
MIL. 2450 lbs.	S. L.			6900 Gal. 6.5 lbs./gal.	
NOR. 2000 lbs.	S. L.			ELECTRONICS	
DIMENSIONS		UHF plus Homing Adapter ARC-27 and ARA-25			
		VHF plus Homing Adapter ARC Type 12 and ARA 3A			
		Liaison - Range 1000 Miles			
		Interphone			
Length 92 ft. 0 in.		MISCELLANEOUS			
Height 35 ft. 0 in.					
Wing Span 90 ft. 0 in.					
Wing Area 1400 sq. ft.					
Wing Aspect Ratio 5.78					
Wheel Tread 63 ft. 0 in.					

CONFIDENTIAL

Loading and Performance -- Typical Mission

CONDITIONS	BASIC	FERRY RANGE
TAKE-OFF WEIGHT	107,285	129,000
Fuel at 6.5 lb/gal	44,750	71,594
Payload (outbound)	8,000	0
Payload (inbound)	4,000	0
Take-off thrust loading	5.48	6.59#/#
Disc loading		
Wing loading	76.6	92.2
Take-off ground run at 6000 ft. and 95 F/clear 50 ft.	0/0	
Maximum Speed at S. L.	364	350
Maximum Speed at 10000 ft.	347	315
Max. rate of climb at S. L.	800	369
Time: SL to 10000 ft.	17.7	
Time: SL to 25000 ft.		
Service ceiling (100 fpm)	13,600	6,500
COMBAT RADIUS OF RANGE		
Average Cruising Speed	425	1,570
Cruising altitude (20% @ S. L.)	300	318
FIRST LANDING WEIGHT	10,000	S. L.
Ground roll at 6000 ft. and 95 F	88,336	
COMBAT WEIGHT		
Cruise altitude	75,736	64,566
Cruise speed	10,000	
Service ceiling (100 fpm)	300	
Take-off ground run at 6000 ft and 95 F/clear 50 ft	25,000	29,750
Max. rate of climb at S. L.	0/0	
Time: SL to 10000 ft	1,540	1,850
Time: SL to 25000 ft	7.55	6.1
Max. speed at S. L.	32.4	22.3
Max. speed at 10000 ft.	377	383
LANDING WEIGHT	382	387
Ground roll at 6000 ft. and 95 F	62,606	64,566
	0	0

- NOTES
- ① Military power
 - ② Normal power
 - ③ Detailed description of missions are given on Page 6
 - ④ With 4000# return payload - no fuel added.

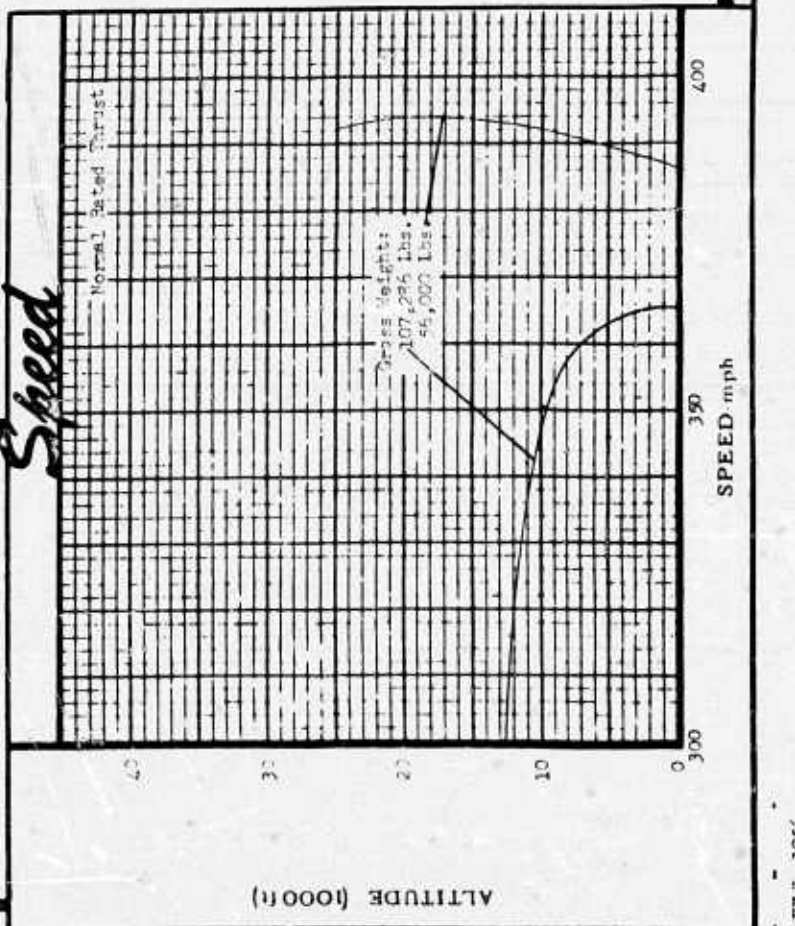
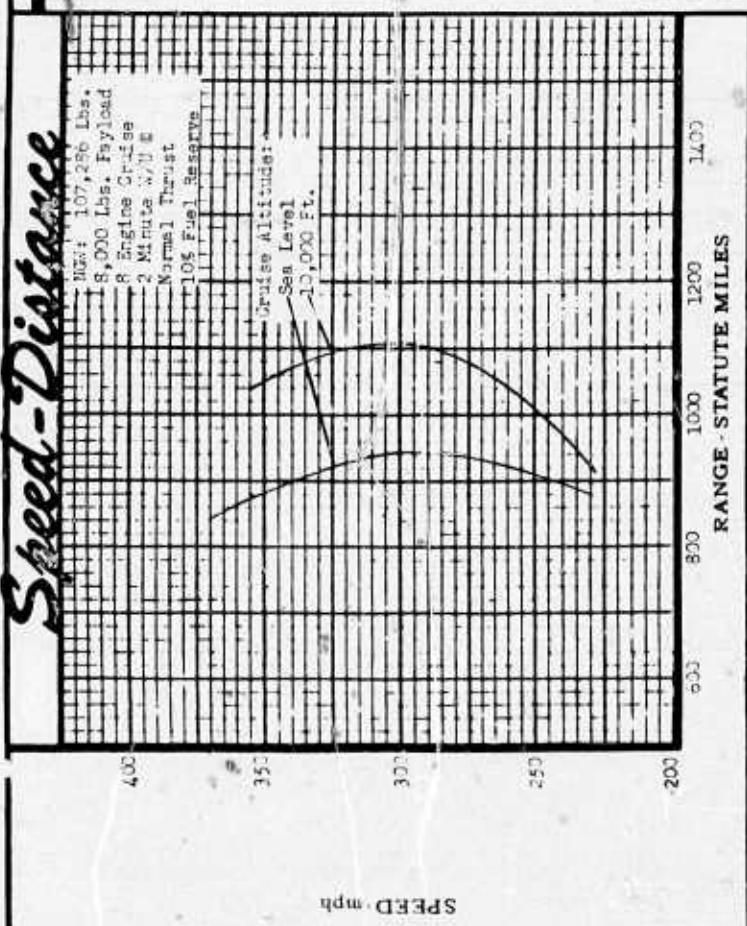
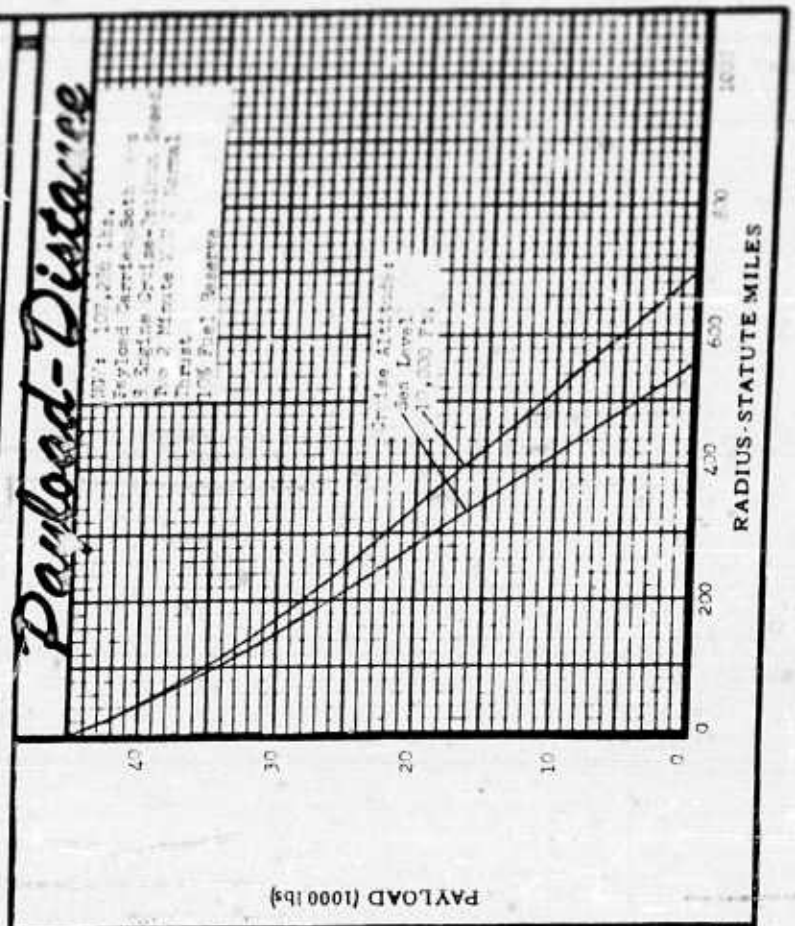
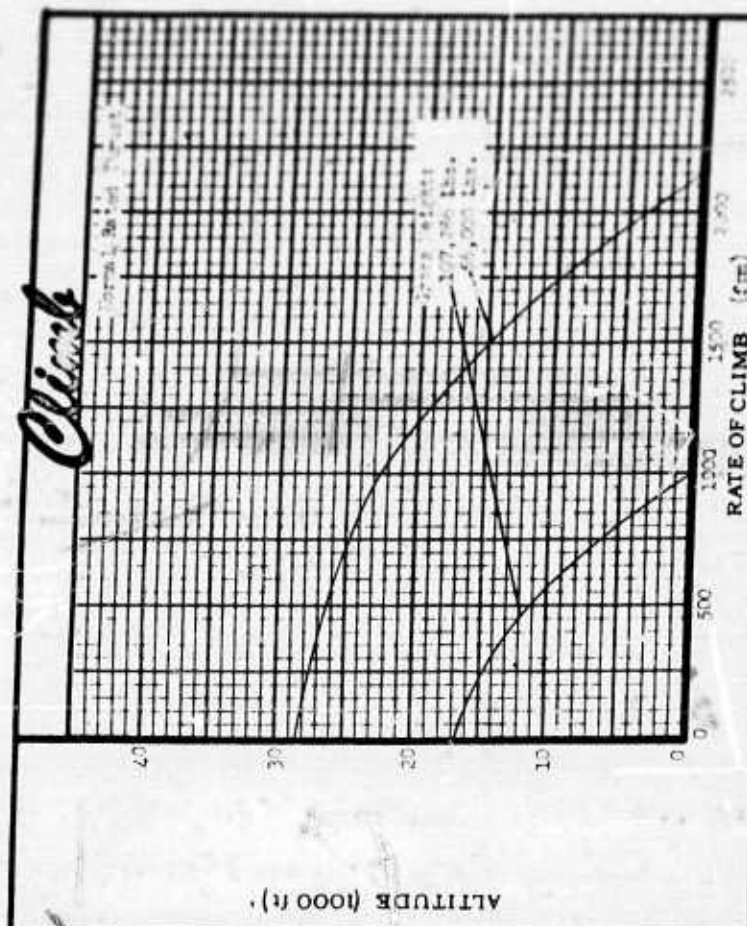
PERFORMANCE BASIS:

- (a) Data source: Estimated
- (b) Performance is based on powers shown on Page 3
- (c) Data do not include ground effect.

July 1956

Special Hovering Turboprop

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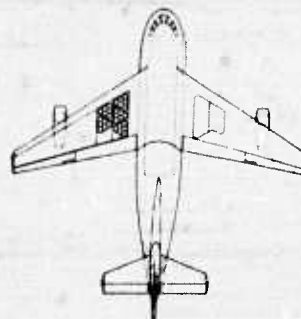
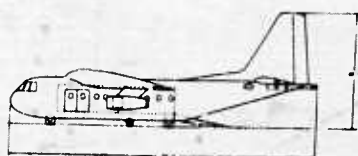


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- I. The design or basic mission of the aircraft is essentially that of a military transport suitable for transporting either troops or associated equipment with the additional requirement for a vertical take-off capability to increase its mobility in the absence of unprepared landing surfaces.
- II. The basic mission requirements in addition to the capability of hovering @ 6,000' and 95°F with military power consist of the following:
 1. Two minute warm-up @ normal power prior to take-off.
 2. Take-off vertically with 8,000# payload and climb on course to 10,000' with normal power.
 3. Cruise at 10,000', 80 per cent of the required radius (425 statute miles), descend to sea and cruise the remaining 20% to the destination.
 4. Hover allowance of 5 minutes @ sea level for vertical take-off and landing operation.
 5. Return cruise with 4000# payload is initially @ sea level again for 20% of the required radius followed by a normal power climb to 10,000'. Remaining cruise at 10,000' completes the 425 statute mile radius requirement.
 6. Fuel allowances include 10% for reserve with a 5% increase in manufacturer's SFC values.
- III. An additional ferry mission applicable to this aircraft consists of the following:
 1. Two minute warm-up @ normal power prior to take-off.
 2. With a 20% increase in normal gross weight take-off and climb on course with normal power to 1000'.
 3. At 1000' cruise out a maximum distance prior to landing with a 10% fuel reserve.
 4. Manufacturer's SFC values increased 5%.

CONFIDENTIAL

Characteristics Summary



AVAILABILITY			PROCUREMENT			
Number available			Number to be delivered in fiscal years			
ACTIVE	RESERVE	TOTAL				

STATUS

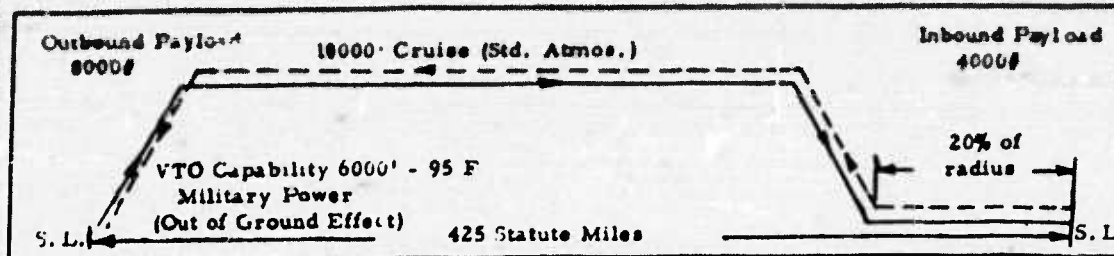
POWER PLANT	FEATURES	GENERAL
(68) General Electric J-85 Turbojets (60-Hover 8-Fwd) Engine Ratings Static Thrust Alt MIL: 2,450 lbs. S.L. HOR: 2,000 lbs. S.L.	Rear aperture loading ramp. Cargo floor at truck bed loading height.	Crew 3 Troops 35 Cabin Floor Area 315 sq.ft Cabin Volume 2,520 cu.ft

JULY, 1966

SPECIAL HOVERING TURBOJET

CONFIDENTIAL

Characteristics Summary Basic Mission

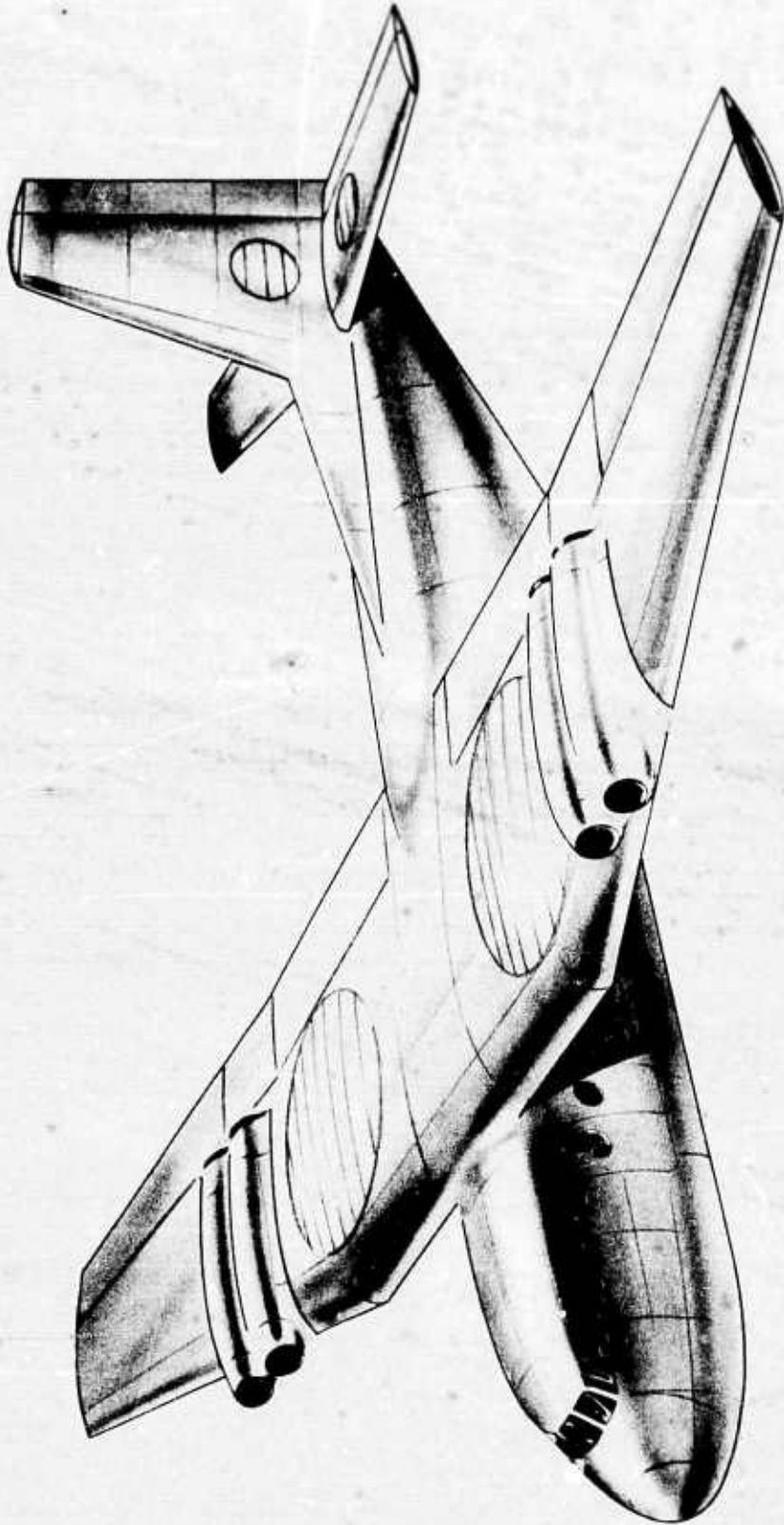


PERFORMANCE		
COMBAT RADIUS	FERRY RANGE	S P E E D
425 Stat. Mi. with 8000 lb payload at 300 mph avg.	1110 Stat. Mi. with 6900 gal. fuel at 300 mph avg. at 107,286 lb T.O. wt.	MAX 364 mph at Sea Level ft alt, N.R.P. MAX 347 mph at 10,000 ft alt, N.R.P.
C L I M B	C E I L I N G	T A K E - O F F
800 fpm sea level, take-off weight normal power	13600 ft 100 fpm, take-off weight normal power	Vertical Take-Off
330 fpm 10000 ft take-off weight normal power		
L O A D	W E I G H T S	H O V E R I N G C E I L.
Crew 600 lbs Payload 8000 lbs Fuel 44750 lbs Oil 1360 lbs	Useful 55,780 lb Empty 51,506 lb Take-Off 107,286 lb	6000 ft., take-off Military Power 95° F Ambient Temperature

N O T E S

1. Performance Basis:
 - (a) Data Source: Estimated
 - (b) Performance is Based on Powers Shown on Page 3
 - (c) Data do not include Ground Effect

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Standard Aircraft Characteristics

VTOL COMPARATIVE STUDY

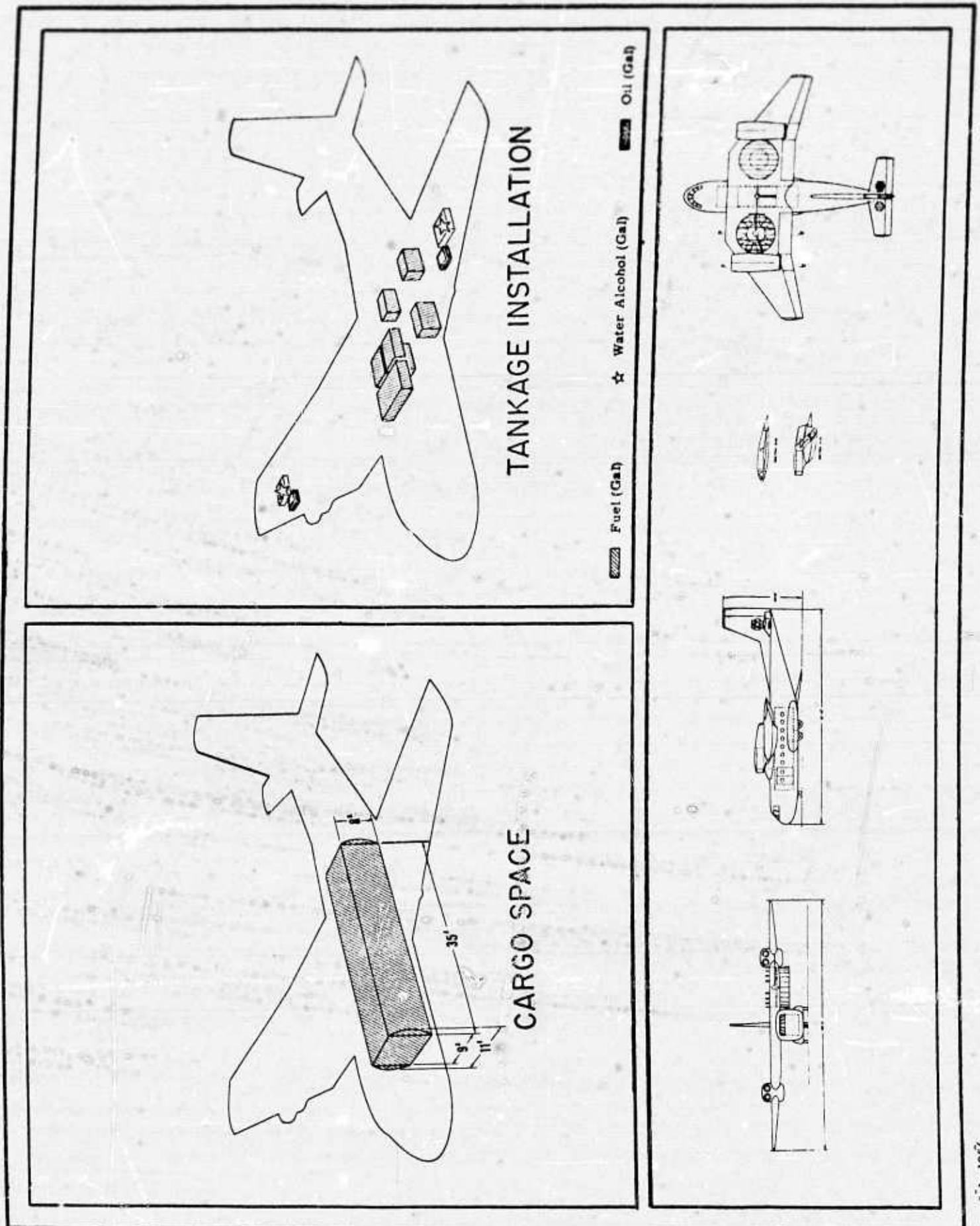
"VERTODYNE"

REPORT R-83

VERTOL AIRCRAFT CORP.

CONTRACT No. R 1681(00)

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July 1956

Vertodyne

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POWER PLANT		Mission and Description		WEIGHTS	
No. and Model	(4) J-79	The basic mission given in detail in the notes is to provide air transportation for troops and cargo with specific requirements for VTOL operation and a radius capability of 425 statute miles. The Vertodyne derives its VTOL capabilities by means of interconnected ducted fans located in the inboard section of the wing. The ducted fans are mechanically driven by a power turbine separated by means of ducting from the gas generator of four modified J-79 turbojets. The engines are mounted horizontally on the wing outboard of the ducted fans so that they operate as conventional turbojets in forward flight and as turboprops in the hovering condition. Pitch and yaw control is obtained from shaft driven tail fans while control in roll is obtained by differential thrust of the main lifting fans.		Normal Gross Wt. VTOL 6000' @ 95°F = 113,958 lb.	
Manufacturer	General Electric			Weight Empty = 66,910 lb.	
Eng. Spec No.	R55AGT400				
ENGINE RATINGS		FUEL		ELECTRONICS	
STATIC THRUST ALT.		Normal Internal		UHF plus Homing Adapter ARC-27 and ARA-25	
MIL.	10,000 lbs. S. L.	5760 Gal. 6.5 lbs./gal		VHF plus Homing Adapter ARC Type 12 and ARA 8A	
NOR.	9,700 lbs. S. L.			Liaison - Range 1600 Miles	
DIMENSIONS		MISCELLANEOUS		Interphone	
Length 91 ft. 0 in.					
Height 34 ft. 9 in.					
Wing Span 106 ft. 0 in.					
Wing Area 2284					
Wing Aspect Ratio 4.91					
Wheel Tread 13 ft. 6 in.					

Vertodyne

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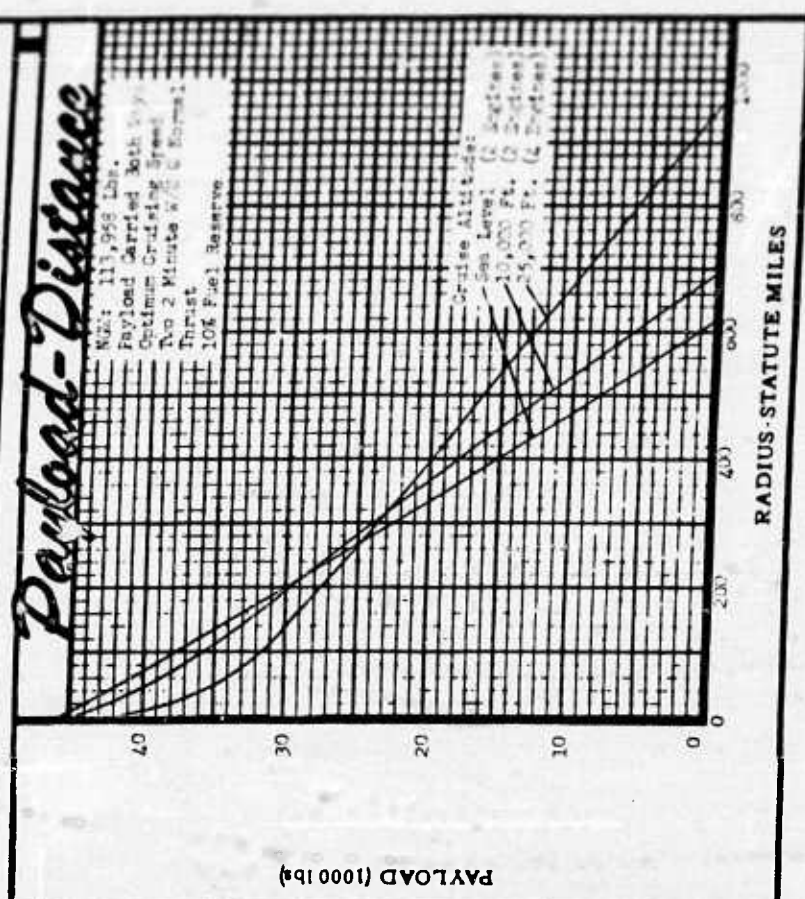
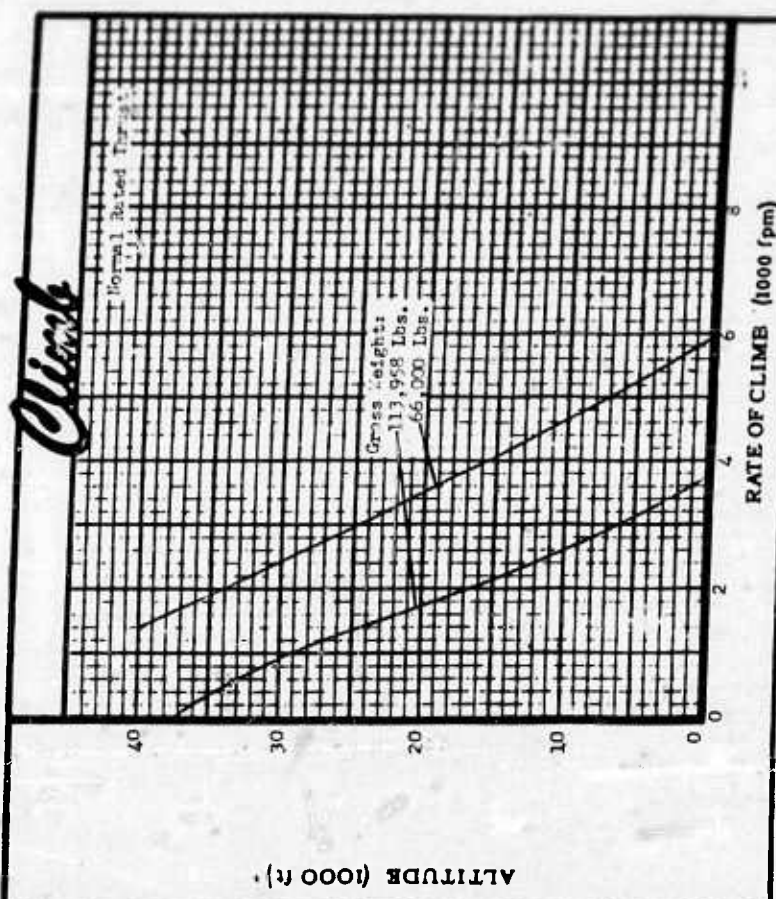
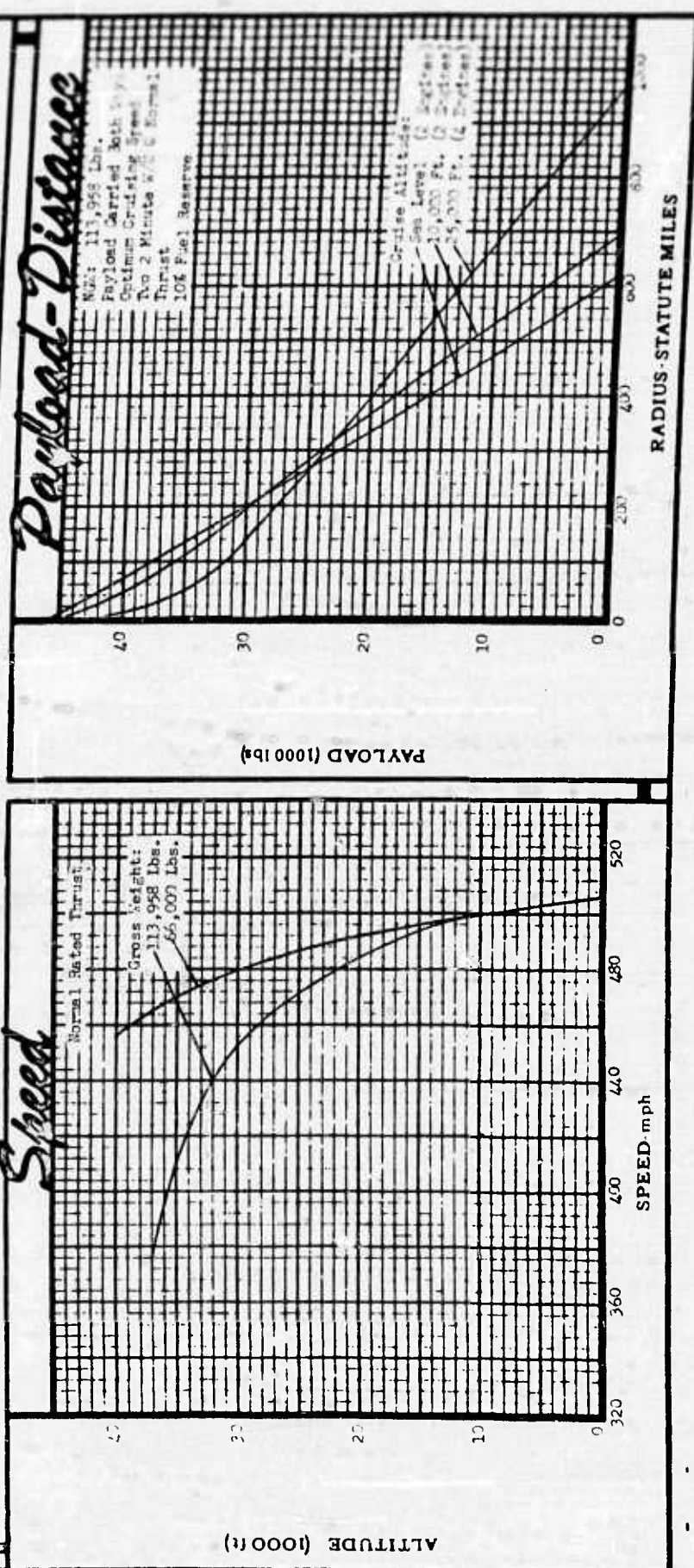
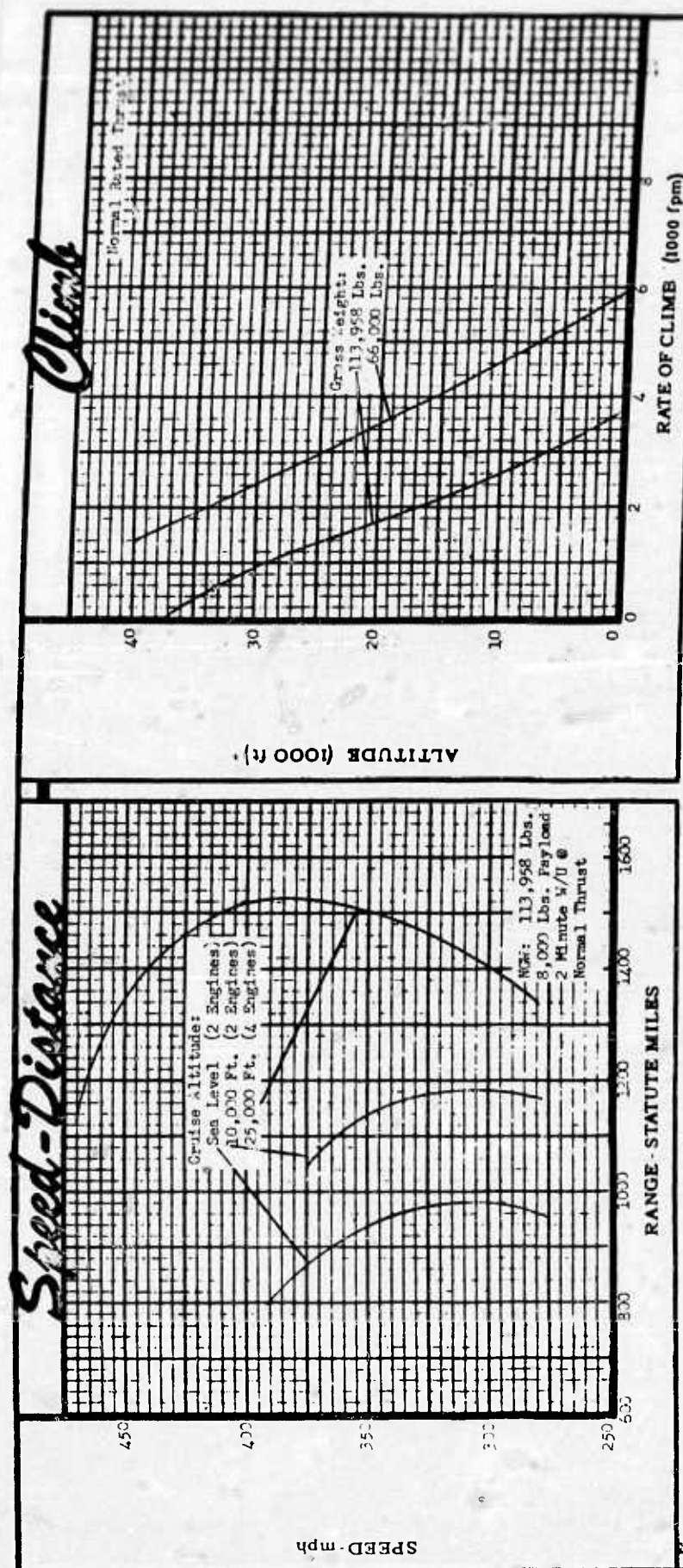
Loading and Performance - Typical Mission

CONDITIONS	BASIC	FERRY RANGE
TAKE-OFF WEIGHT	113,958	136,900
Fuel at 6.5 lb/gal	37,510	65,358
Payload (outbound)	8,000	0
Payload (inbound)	4,000	0
Take-off power loading	2.1	2.52
Disc loading	259	311
Wing loading	49.8	60.0
Take-off ground run at 6000 ft. and 95 F/clear 50 ft.	0/0	
Maximum Speed at S. L.	506	506
Maximum Speed at 10000 ft.	500	500
Max. rate of climb at S. L.	3,660	3,200
Time: SL to 10000 ft.	3.40	3.7
Time: SL to 25000 ft.	10.59	11.9
Service ceiling (100 fpm)	37,000	33,500
COMBAT RADIUS OF RANGE	425	2,480
Average Cruising Speed	400	420
Cruising altitude (20% @ S. L.)	10,000	25,000
FIRST LANDING WEIGHT	97,433	
Ground roll at 6000 ft. and 95 F	0	
COMBAT WEIGHT	90,773	78,438
Cruise altitude	10,000	
Cruise speed	400	
Service ceiling (100 fpm)	42,500	44,500
Take-off ground run at 6000 ft and 95 F/clear 50 ft	0/0	
Max. rate of climb at S. L.	4,450	5,100
Time: SL to 10000 ft	2.7	2.20
Time: SL to 25000 ft	8.82	6.95
Max. speed at S. L.	506	506
Max. speed at 10000 ft.	500	500
LANDING WEIGHT	76,198	78,438
Ground roll at 6000 ft. and 95 F	0	0

- NOTES
- 1 Military power
 - 2 Normal power
 - 3 Detailed description of missions are given on Page 6
 - 4 With 4000# return payload - no fuel added.

PERFORMANCE BASIS:
(a) Data source: Estimated
(b) Performance is based on powers shown on Page 3
(c) Data do not include ground effect.

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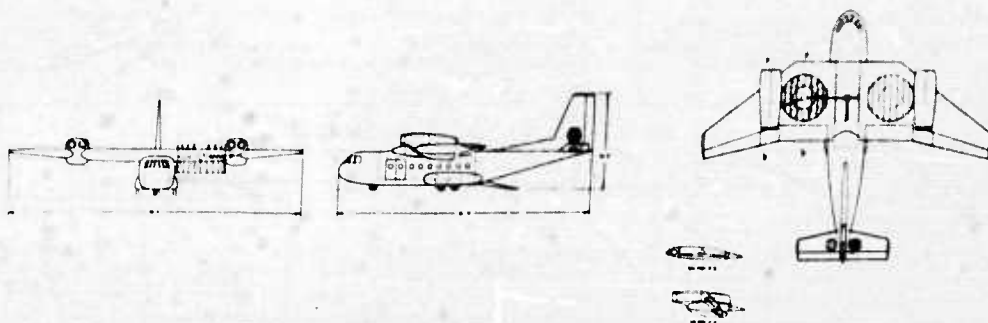
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N O T E S

- I. The design or basic mission of the aircraft is essentially that of a military transport suitable for transporting either troops or a associated equipment with the additional requirement for a vertical take-off capability to increase its mobility in the absence of unprepared landing surfaces.
- II. The basic mission requirements in addition to the capability of hovering @ 6,000' and 95°F with military power consist of the following:
 1. Two minute warm-up @ normal power prior to take-off.
 2. Take-off vertically with 8,000# payload and climb on course to 10,000' with normal power.
 3. Cruise at 10,000', 80 per cent of the required radius (425 statute miles), descend to sea and cruise the remaining 20% to the destination.
 4. Hover allowance of 5 minutes @ sea level for vertical take-off and landing operation.
 5. Return cruise with 4000# payload is initially @ sea level, gain for 20% of the required radius followed by a normal power climb to 10,000'. Remaining cruise at 10,000' completes the 425 statute mile radius requirement.
 6. Fuel allowances include 10% for reserve with a 5% increase in manufacturer's SFC values.
- III. An additional ferry mission applicable to this aircraft consists of the following:
 1. Two minute warm-up @ normal power prior to take-off.
 2. With a 20% increase in normal gross weight take-off and climb on course with normal power to 25,000'.
 3. At 25,000' cruise out a maximum distance prior to landing with a 10% fuel reserve.
 4. Manufacturer's SFC values increased 5%.

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Characteristics Summary



AVAILABILITY			PROCUREMENT			
Number available			Number to be delivered in fiscal years			
ACTIVE	RESERVE	TOTAL				

STATUS

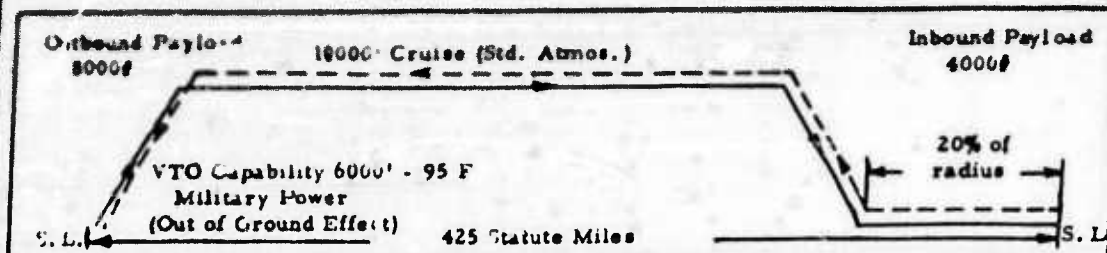
POWER PLANT	FEATURES	GENERAL
(+) General Electric J-79 Turbojets Engine Ratings Static Thrust Alt MIL: 10,000 lbs. S.L. NOR: 9,200 lbs. S.L.	Rear aperture loading ramp. Cargo floor at truck bed loading height.	Crew 3 Troops 35 Cabin Floor Area 315 sq.ft. Cabin Volume 2,520 cu.ft.

JULY, 1955

VERTODYNE

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Characteristics Summary Basic Mission



PERFORMANCE

COMBAT RADIUS	FERRY RANGE	S P E E D
425 Stat. Mi. with 8000 lb payload at 400 mph avg.	1530 Stat. Mi. with 5770 gal. fuel at 385 mph avg. at 113,958 lb T.O. wt. and 8000 lbs payload	MAX 506 mph at Sea Level ft alt, N.R.P. MAX 500 mph at 10,000 ft alt, N.R.P.
CLIMB	CEILING	TAKE-OFF
3650 fpm sea level, take-off weight normal power	37000 ft 100 fpm, take-off weight normal power	Vertical Take-Off
2550 fpm 10000 ft take-off weight normal power		
LOAD	WEIGHTS	HOVERING CEIL.
Crew 600 lbs Payload 8000 lbs Fuel 37510 lbs Oil 300 lbs	Useful 47048 lb Empty 66910 lb Take-Off 113,958 lb	6000 ft., take-off Military Power 95° Ambient Temperature

NOTES

1. Performance Basis:
 - (a) Data source, Estimated
 - (b) Performance is Based on Powers Shown on Page 3
 - (c) Data do not include Ground Effect

July 1956

Vertodyne

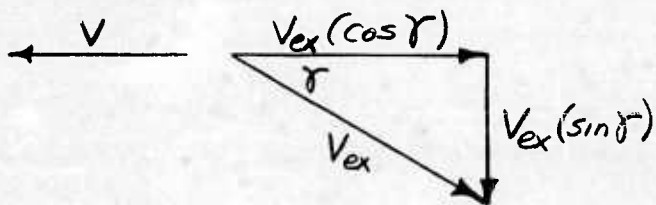
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VECTODYNE - FORWARD FLIGHT PERFORMANCE

In the broad parametric analysis (Reference (a)) performance evaluation for the "Vectodyne" concept was estimated from equations which were arrived at following a series of discussions with Dr. Lippisch of Collins Radio Corporation and considered adequate for the study at the time.

However, the methods used have been altered to better reflect the thrust and power requirements for the Vectodyne and are based on the momentum and energy principles.

If a mass of air is directed through a duct which is moving at some velocity (V) and deflected through an angle (γ) so that its exit velocity (V_{ex}) is greater than (V), a velocity diagram for this condition would be as follows:



- V = forward speed (f.p.s.)
- V_{ex} = velocity of air at exit of duct (f.p.s.)
- γ = angle of deflection of air mass
- ρ = density of air (slugs/ft.³)
- f = equivalent flat plate of aircraft (ft.²)
- A_{ex} = exit area of duct (ft.²)

The mass flow of air at the duct's exit multiplied by the net horizontal velocity would give the force available in the horizontal direction. Now if $V_{ex} >$ than V so that the net horizontal velocity

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is $(V_{ex} \times \cos \delta - V)$, then the horizontal force (T_H) will be:

$$T_H = (\rho A_{ex} V_{ex})(V_{ex} \cos \delta - V) \quad (1)$$

Since $V_{ex} > V$, the horizontal force (T_H) can be utilized to overcome the drag (D_p) of an aircraft traveling at a velocity (V), and since $D_p = \frac{1}{2} \rho V^2 f$ then:

$$D_p = T_H \quad (1a)$$

$$\text{or } \frac{1}{2} \rho V^2 f = \rho A_{ex} V_{ex} (V_{ex} \cos \delta - V)$$

Similarly, the net velocity in the vertical direction ($V_{ex} \sin \delta$) multiplied by the mass flow of air at the duct's exit would give the force available in the vertical direction:

$$T_V = (\rho A_{ex} V_{ex})(V_{ex} \sin \delta) \quad (2)$$

This force (T_V) must be equal to the weight (W) of the aircraft traveling at velocity (V) in level forward flight.

$$\text{or } W = T_V = (\rho A_{ex} V_{ex})(V_{ex} \sin \delta) \quad (2a)$$

The horsepower required (P) to move the aircraft traveling at velocity (V) in level forward flight must equal the change in Kinetic energy per second:

$$P = \frac{\left(\frac{\rho A_{ex} V_{ex}}{2}\right) V_{ex}^2 - \left(\frac{\rho A_{ex} V_{ex}}{2}\right) V^2}{550} \quad (3)$$

$$\text{or, } P = \frac{\rho A_{ex} V_{ex}}{1100} (V_{ex}^2 - V^2) \quad (3a)$$

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In order to incorporate the effect of compressibility and drag at higher forward speeds, equation (1a) should be altered as follows:

$$\frac{1}{2} \rho V^2 f\left(\frac{C_{d_0}}{C_{d_{inc}}}\right) = \rho A_{ex} V_{ex} (V_{ex} \cos \gamma - V) \quad (1b)$$

Now, solving equation (1b) for V_{ex} the following expression is obtained:

$$V_{ex} = V \left[\frac{2A_{ex} \pm \sqrt{4A_{ex}^2 + 8A_{ex}(\cos \gamma) f\left(\frac{C_{d_0}}{C_{d_{inc}}}\right)}}{4A_{ex}(\cos \gamma)} \right]$$

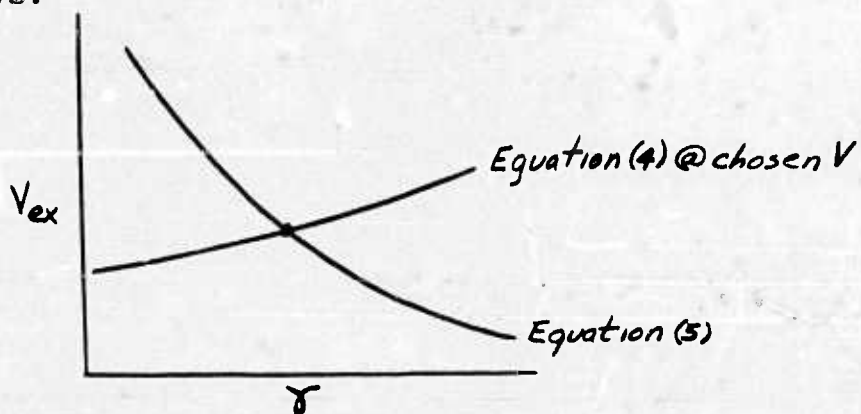
$$\text{let } \beta = \left[\frac{2A_{ex} \pm \sqrt{4A_{ex}^2 + 8A_{ex}(\cos \gamma) f\left(\frac{C_{d_0}}{C_{d_{inc}}}\right)}}{4A_{ex}(\cos \gamma)} \right]$$

$$\therefore V_{ex} = V(\beta) \quad (4)$$

Solving equation (2a) for V_{ex} , the following expression is obtained:

$$V_{ex} = \sqrt{\frac{W}{A_{ex}(\sin \gamma) \rho}} \quad (5)$$

Equation (4) expresses V_{ex} as a function of forward speed (V) and deflection angle (γ), and equation (5) expresses V_{ex} as a function of (γ) and air density, (ρ), or altitude. For a given set of conditions, i.e., forward speed, altitude, and gross weight, two solutions for V_{ex} can be obtained as a function of γ and plotted as follows:



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The intersection of these two functions yields the required deflection setting (γ) and corresponding exit velocity (V_{ex}) necessary to maintain level forward flight at the chosen forward speed (V) and given set of conditions.

The power required for this set of conditions can now be easily obtained from equation (3a) rearranged as follows:

$$SHP_{REQ} = \frac{1}{\eta_t} \left(\frac{\rho A_{ex}}{1100} \right) V \beta \left[(V\beta)^2 - V^2 \right] \quad (6)$$

or
$$SHP_{REQ} = \frac{\rho A_{ex}}{\eta_t (1100)} V^3 \beta (\beta + 1) (\beta - 1)$$

where, η_t accounts for transmission and duct losses and propeller efficiency.

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Standard Aircraft Characteristics

VTOL COMPARATIVE STUDY

"VECTODYNE"

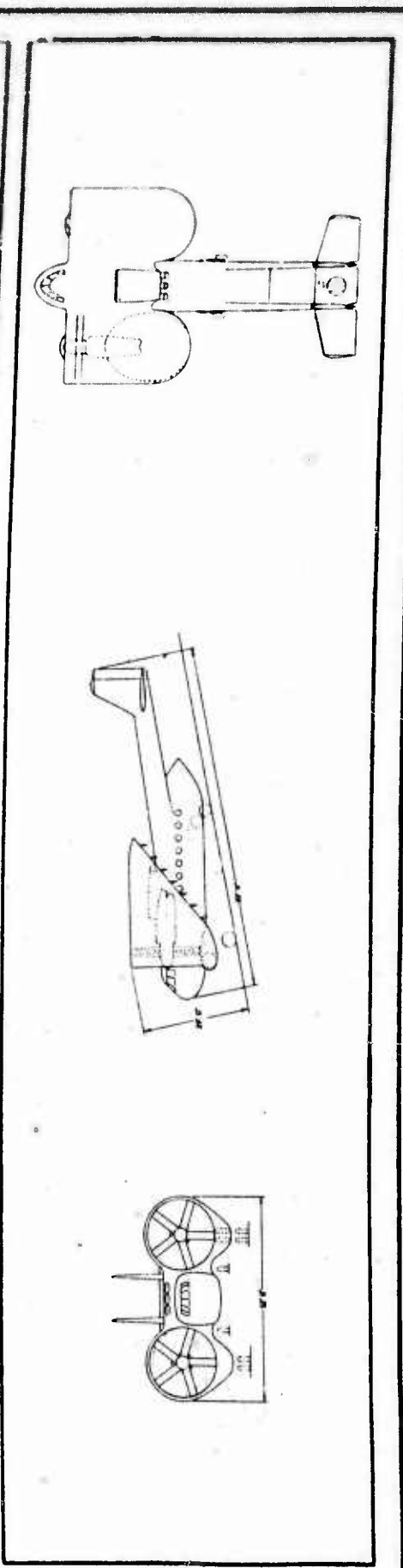
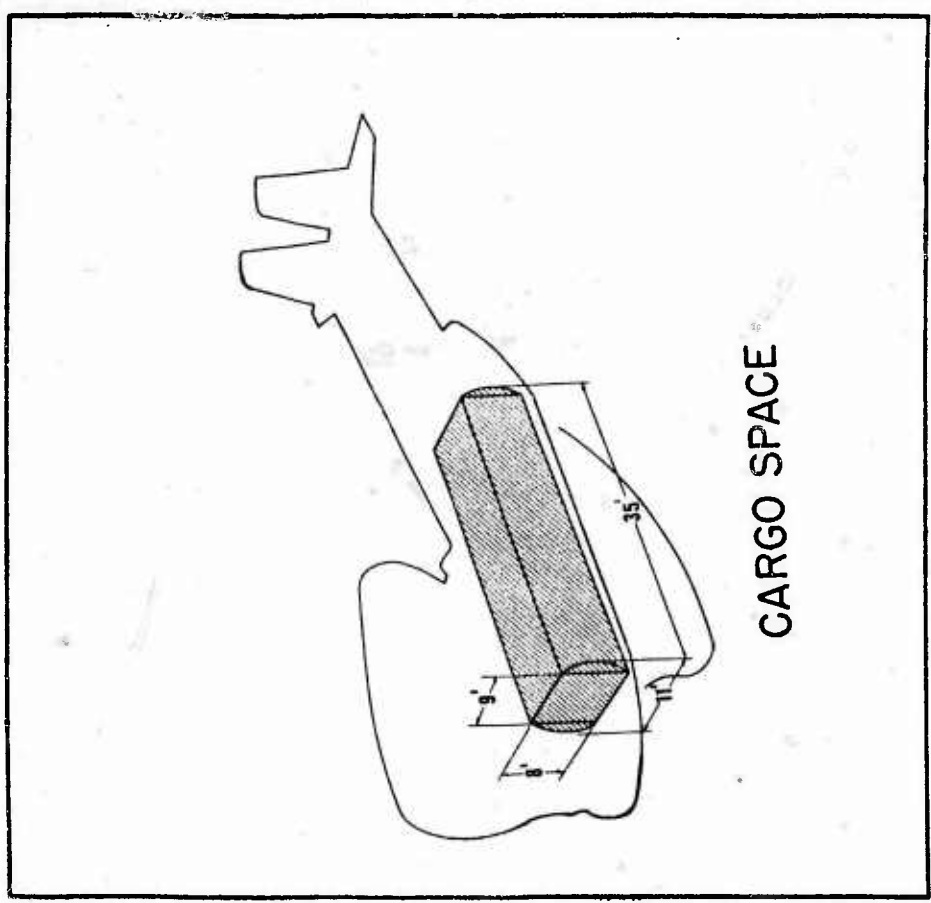
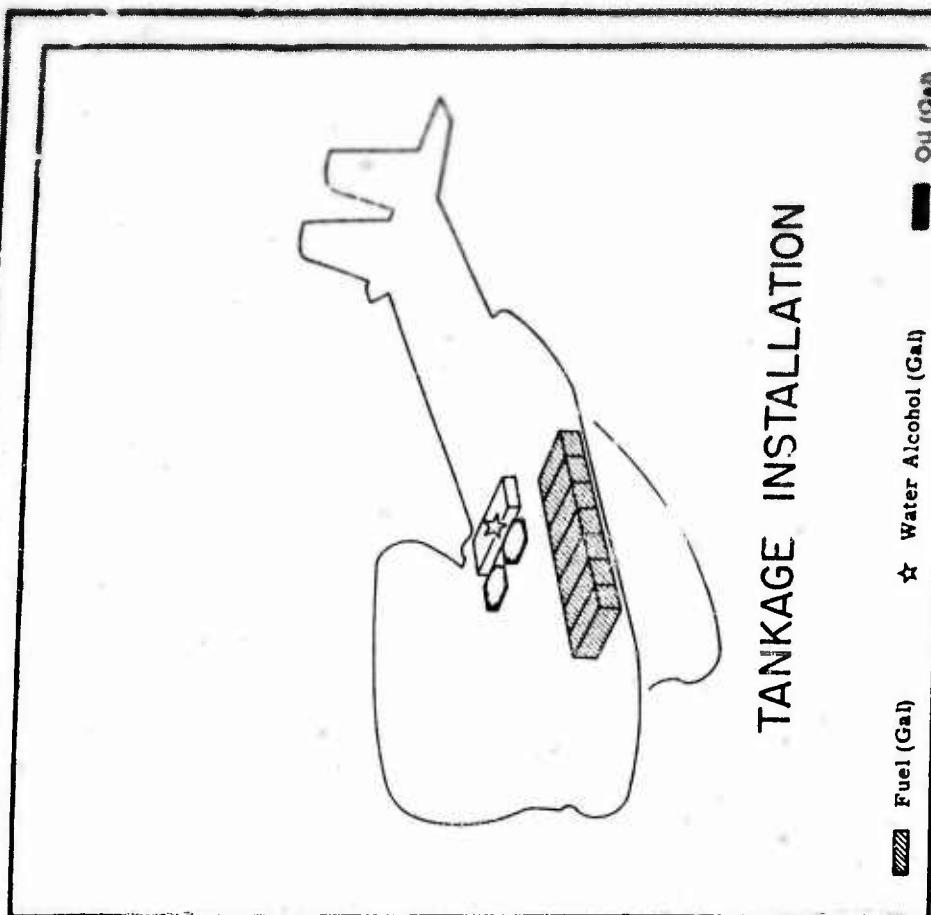
(AERODYNE PRINCIPLE)

VERTOL AIRCRAFT CORP.

CONTRACT NONR 1681(OO)

REPORT R-83

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Vector Inc.

July 1956

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POWER PLANT		Mission and Description		WEIGHTS	
No. and Model	(9) 550 B-1	The basic mission given in detail in the notes is to provide air transportation for troops and cargo with specific requirements for VTOL operation and a radius capability of 425 statute miles. This aircraft employs two outboard mounted counter-rotating ducted propellers which supply airflow to controllable deflector vanes mounted horizontally at the exit of the ducts. The position of these vanes controls the direction of thrust for both the hovering and forward flight condition. The propellers are interconnected with the power plants, three of which are located in each of two outboard nacelles and the remaining three atop the fuselage. Both yaw and roll control are obtained through adjustment of the propeller pitch and deflector vanes working in combination. Pitch control is obtained from a single ducted tail fan centrally located within the horizontal tail surface and interconnected with the main power source.		Normal Gross Wt. VTOL - 6000' @ 95° F = 121,790 lb.	
Manufacturer	Allison			Weight Empty 72,380 lb.	
Eng. Spec No.	394-B				
ENGINE RATINGS				FUEL	
SHP	RPM	ALT.		Normal Internal	
T. O.	5168	S. L.		5840 Gal. 6.5 lbs./gal.	
MIL.	5168	S. L.			
NOR.	4590	S. L.			
DIMENSIONS		MISCELLANEOUS		ELECTRONICS	
Length	87 ft. 9 in.			UHF plus Homing Adapter ARC-27 and ARA-25	
Height	29 ft. 0 in.			VHF plus Homing Adapter ARC Type 12 and APA 8A	
Width	52 ft. 6 in.			Liaison - Range 1000 Miles	
Prop. Dia.	18 ft. 0 in.			Interphone	
Wheel Tread	32 ft. 6 in.				

Vectodyne

July 1956

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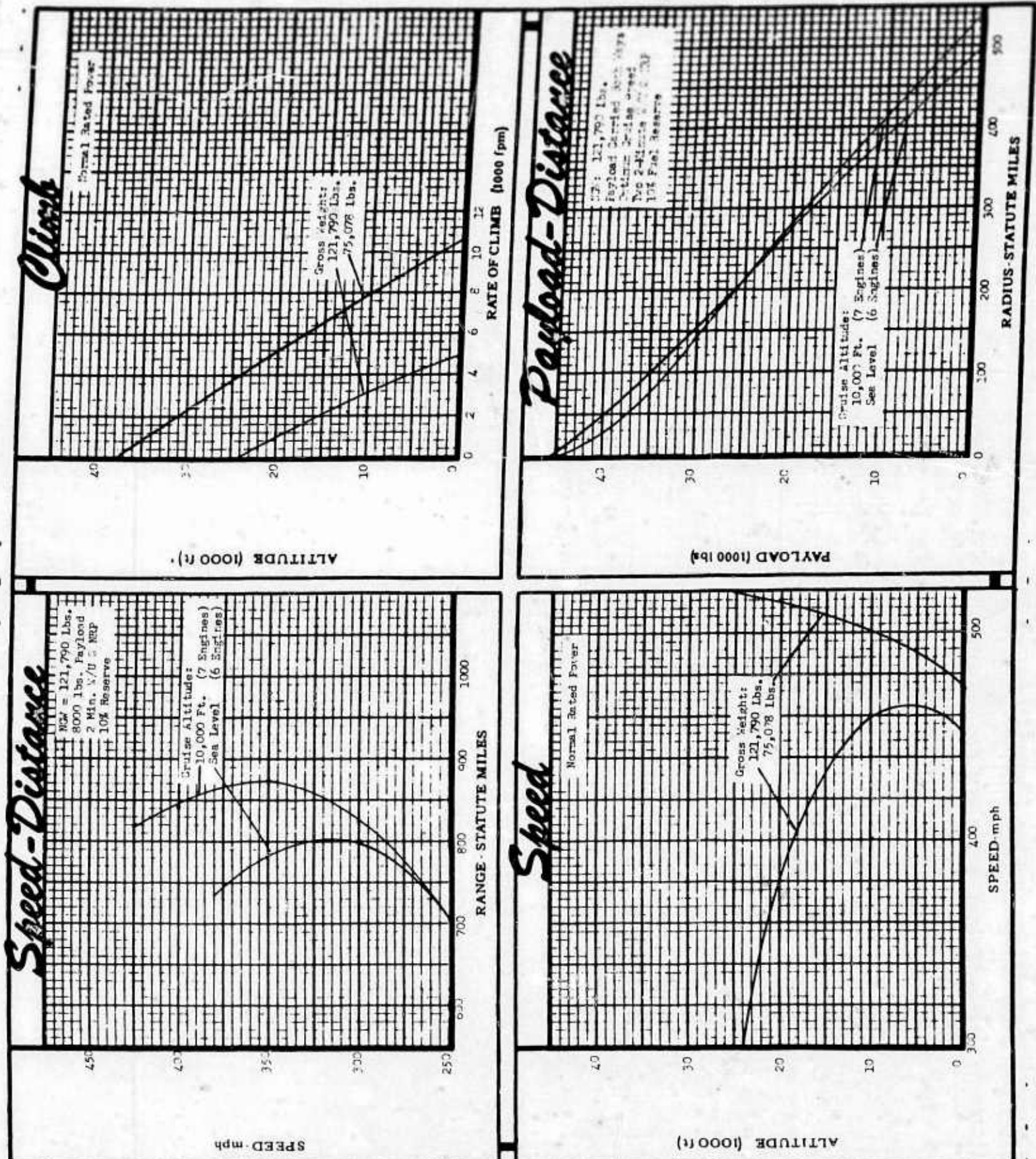
Loading and Performance - Typical Mission

C O N D I T I O N S	BASIC	FERRY RANGE
TAKE-OFF WEIGHT	121,790	145,000
Fuel at 6.5 lb/gal	37,950	66,720
Payload (outbound)	8,000	0
Payload (inbound)	4,000	0
Take-off power loading	2.60	3.12
Disc loading	237	284
Wing loading		
Take-off ground run at 6000 ft. and 95 F/clear 50 ft.	0/0	425
Maximum Speed at S.L.	440	400
Maximum Speed at 10000 ft.	440	3,300
Max. rate of climb at S.L.	5,850	4.55
Time: SL to 10,000 ft.	2.11	
Time: SL to 25000 ft.		15,000
Service ceiling (100 fpm)	24,000	1,185
COMBAT RADIUS OF RANGE	425	320
Average Cruising Speed	375	S.L.
Cruising altitude (20% @ S.L.)	10,000	
FIRST LANDING WEIGHT	103,040	
Ground roll at 6000 ft. and 95 F	0	84,950
COMBAT WEIGHT	97,050	
Cruise altitude	10,000	35,000
Cruise speed	350	
Service ceiling (100 fpm)	32,400	
Take-off ground run at 6000 ft and 95 F/clear 50 ft	0/0	11,500
Max. rate of climb at S.L.	9,100	.95
Time: SL to 10000 ft	1.15	3.25
Time: SL to 25000 ft	4.54	470
Max. speed at S.L.	462	494
Max. speed at 10000 ft.	483	84,950
LANDING WEIGHT	82,730	0
Ground roll at 6000 ft. and 95 F	0	

PERFORMANCE BASIS:
(a) Data source: Estimated
(b) Performance is based on powers shown on Page 3
(c) Data do not include ground effect.

NOTES
① Military power
② Normal power
③ Detailed description of missions are given on Page 6
④ With 4000# return payload - no fuel added.

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NOTES

I. The design or basic mission of the aircraft is essentially that of a military transport suitable for transporting either troops or associated equipment with the additional requirement for a vertical take-off capability to increase its mobility in the absence of unprepared landing surfaces.

II. The basic mission requirements in addition to the capability of hovering @ 6,000' and 95% with military power consist of the following:

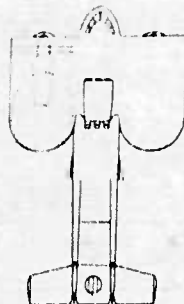
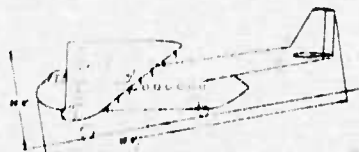
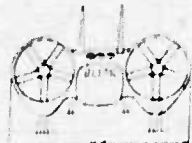
1. Two minute warm-up @ normal power prior to take-off.
2. Take-off vertically with 8,000# payload and climb on course to 10,000' with normal power.
3. Cruise at 10,000', 80 per cent of the required radius (425 statute miles). Descend to sea and cruise the remaining 20% to the destination.
4. Hover allowances @ 5 minutes @ sea level for vertical take-off and landing operation.
5. Return cruise with 4000# payload is initially @ sea level again for 20% of the required radius followed by a normal power climb to 10,000'. Remaining cruise at 10,000' completes the 425 statute mile radius requirement.
6. Fuel allowances include 10% for reserve with a 5% increase in Manufacturer's SFC values.

III. An additional ferry mission applicable to this aircraft consists of the following:

1. Two minute warm-up @ normal power prior to take-off.
2. With a 20% increase in normal gross weight take-off and climb on course with normal power to 8000'.
3. At 8000' cruise out a maximum distance prior to landing with a 10% fuel reserve.
4. Manufacturer's SFC values increased 5%.

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Characteristics Summary



A V A I L A B I L I T Y			P R O C U R E M E N T			
Number available			Number to be delivered in fiscal years			
ACTIVE	RESERVE	TOTAL				

S T A T U S	

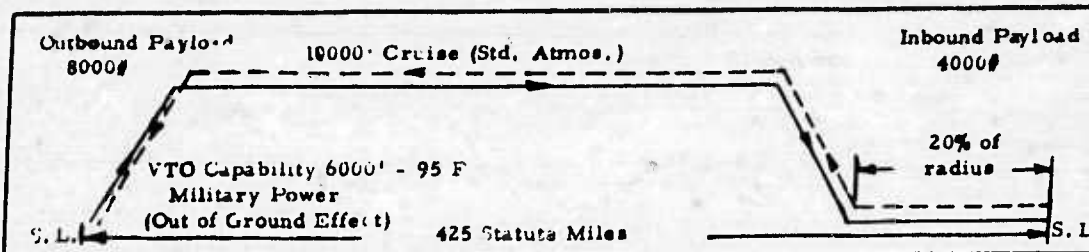
POWER PLANT	F E A T U R E S	GENERAL																
(9) Allison 550 B-1 Turboprops Engine Ratings <table><tr><td></td><td>SHP</td><td>RPM</td><td>ALT</td></tr><tr><td>TO:</td><td>5168</td><td>9900</td><td>S.L.</td></tr><tr><td>MIL:</td><td>5168</td><td>9900</td><td>S.L.</td></tr><tr><td>NOR:</td><td>4590</td><td>9900</td><td>S.L.</td></tr></table>		SHP	RPM	ALT	TO:	5168	9900	S.L.	MIL:	5168	9900	S.L.	NOR:	4590	9900	S.L.	Rear aperture loading ramp. Cargo floor at truck bed loading height.	Crew 3 Troops 35 Cabin Floor Area 315 sq.ft. Cabin Volume 2,520 cu.ft.
	SHP	RPM	ALT															
TO:	5168	9900	S.L.															
MIL:	5168	9900	S.L.															
NOR:	4590	9900	S.L.															

JULY, 1956

VECTODYNE

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Characteristics Summary Basic Mission



PERFORMANCE		
COMBAT RADIUS	FERRY RANGE	S P E E D
425 Stat. Mi. with 8000 lb payload at 360 mph avg.	360 Stat. Mi. with 5840 gal. fuel at 350 mph avg. at 121790 lb T.O. wt. and 8000 lbs. Payload	MAX 450 mph at Sea Level ft alt, N.R.P. MAX 460 mph at 10,000 ft alt, N.R.P.
CLIMB	CEILING	TAKE-OFF
5850 fpm sea level, take-off weight normal power	24000 ft 100 fpm, take-off weight normal power	Vertical Take-Off
3650 fpm 10000 ft take-off weight normal power		
LOAD	WEIGHTS	HOVERING CEIL.
Crew 600 lbs Payload 8000 lbs Fuel 37950 lbs Oil 450 lbs	Useful 49410 lb Empty 72380 lb Take-Off 121,790 lb	6000 ft., take-off Military Power 95° Ambient Temperature

NOTES

1. Performance Basis:
 - (a) Data Source: Estimated
 - (b) Performance is Based on Powers Shown on Page 3
 - (c) Data do not include Ground Effect

July 1956

Vectodyne

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IV. REFERENCES

- (a) Vertol Aircraft Corporation Report R-75 - "Comparative Study of Various Types of VTOL Aircraft - Interim Summary Report."
- (b) Vertol Aircraft Corporation Report R-76 - "Comparative Study of Various Types of VTOL Transport Aircraft - Configuration Studies Report."
- (c) Perkins and Hage - "Airplane Performance, Stability and Control."

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