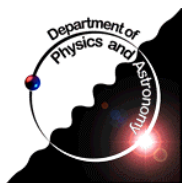


ATLAS Endcap Signal Feedthrough Project

NSERC Review
TRIUMF, Oct 19th 2000

- **Overview of the Project**
- **Main Activities since Jan 2000**
 - **Reception of Components**
 - **Study of Vacuum Cable Properties**
 - **First Production Feedthroughs**
 - **QA/QC and TIS**
 - **Pin Carrier Procurement**
- **Milestones and Schedule**
- **Budget and Management**
- **Conclusions**



Michel Lefebvre
University of Victoria
Physics and Astronomy

Overview of the Project

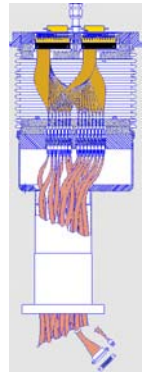
ATLAS liquid argon calorimetry has over 180k signal channels which must come through the cryostats.

Each feedthrough unit carries 1920 electrical channels.

Barrel: 64 feedthrough units

Endcap: 50 feedthrough units total

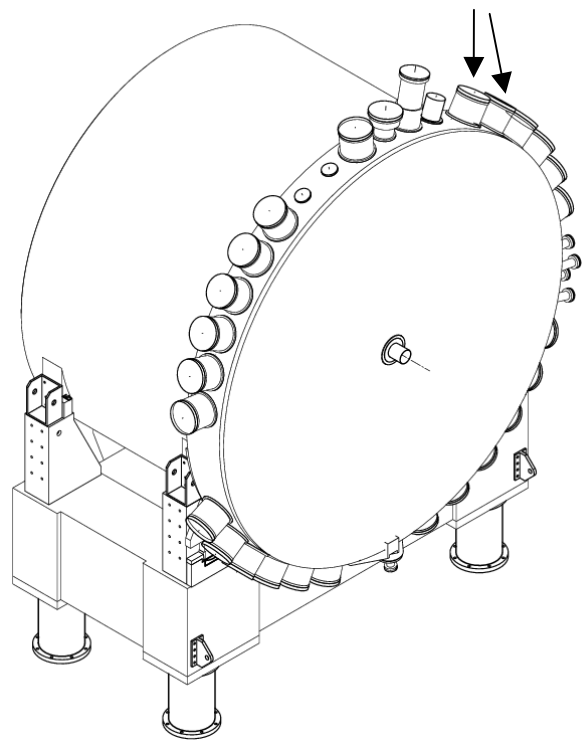
25 on ECC, 25 on ECA



The endcap signal feedthrough project is an ATLAS **common fund** contribution from Canada

Part of the ATLAS Cryostat and Cryogenics Project (Leader: Pierre Pailier)

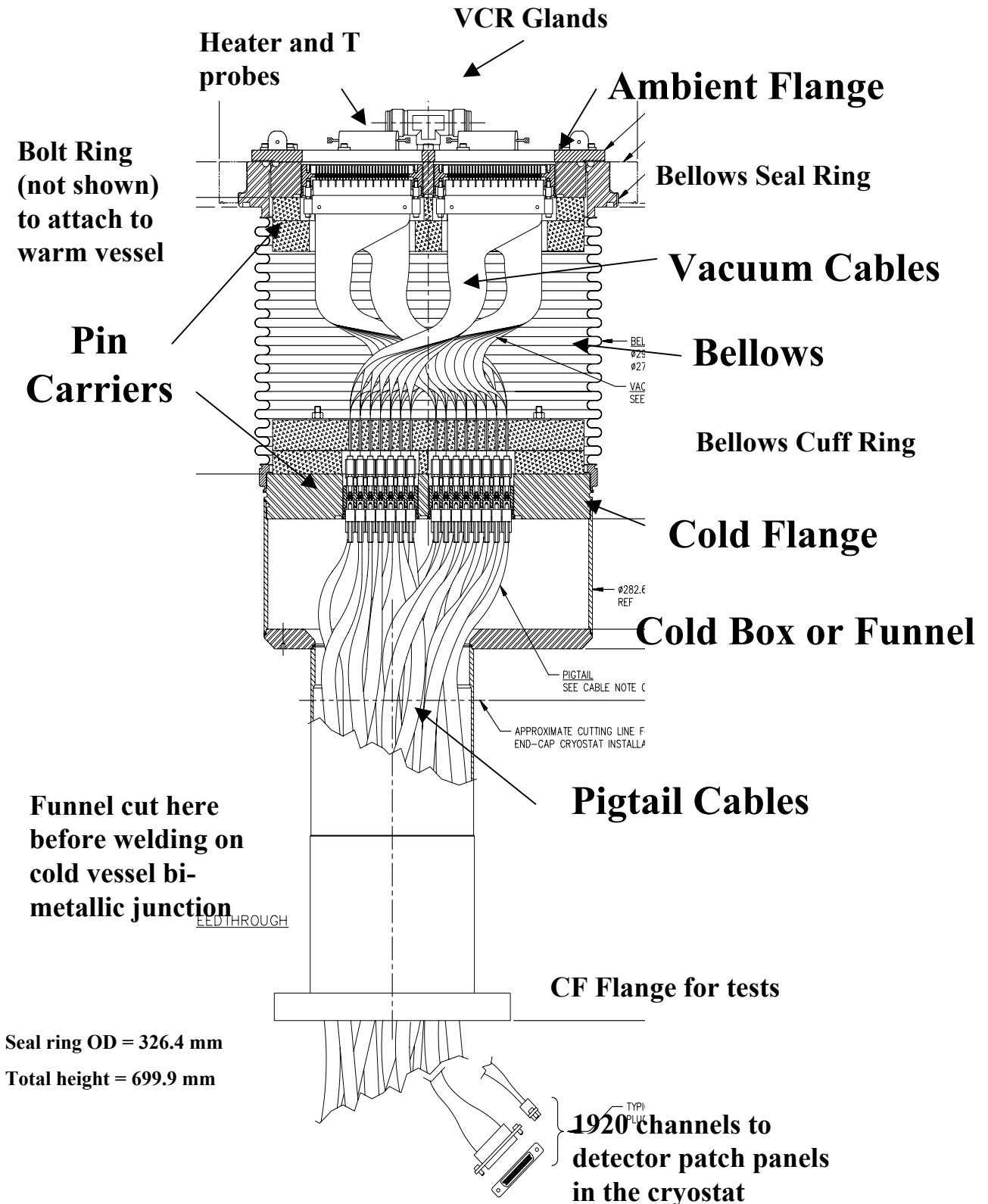
Production Readiness Review successfully passed at CERN on Jan 29th 1999



One endcap cryostat shown during assembly

Overview of the Project

Overall Design



Reception of Components

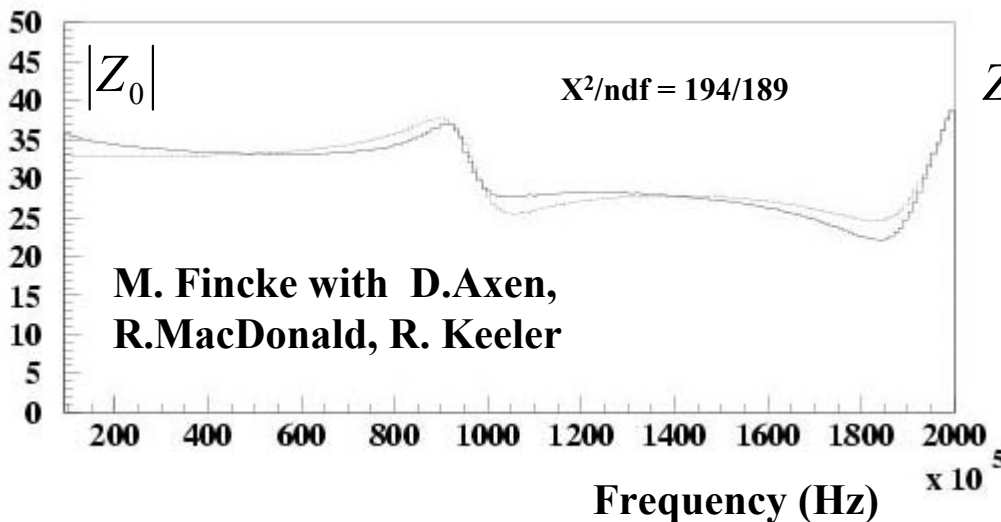
An important activity since Jan 2000 has been the treatment of components upon reception. A few examples:

- **34% of vacuum cables** have been received and fully tested (588 out of 1750);
- **31 % of pigtails from Orsay** have been received (500 out of 1635); About half have been processed, tested and labeled;
- **All cold flanges, warm flanges, seal rings, cuff rings, funnel assemblies, and 90% of all bellows assemblies** have been received and inspected. About half have been cleaned in the ATLAS HEC ultrasonic bath at TRIUMF;
- **VCR Glands** reception from CERN and testing; CERN now to use rubber or plastic gaskets for testing, as per our recommendation.
- **All measurements logged in a production database**

Study of Vacuum Cable Properties

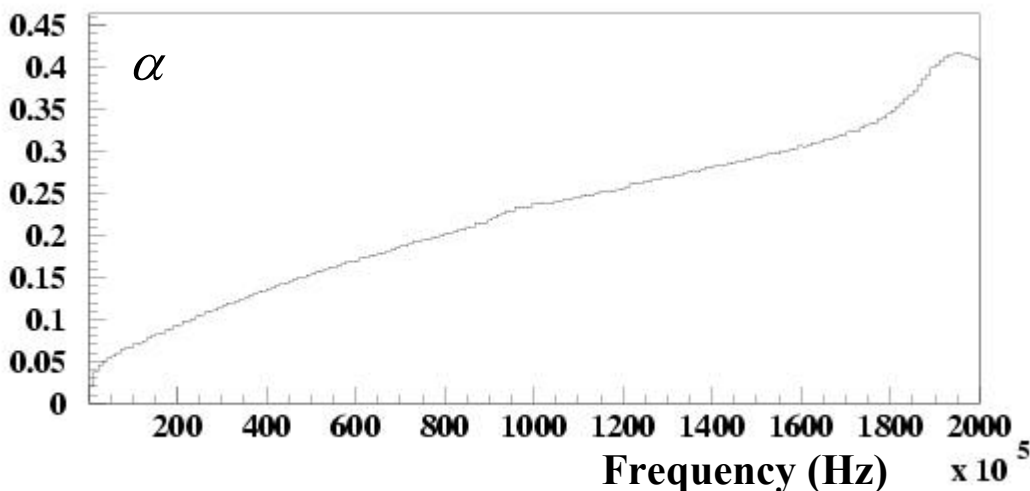
Frequency-dependent properties of Microstrip Transmission Lines

Network-analyzer measurements allow the frequency-dependent determination of the **complex impedance**:



$$Z_0 = \sqrt{Z_{oc} Z_{sc}}$$
$$= \sqrt{\frac{R + i\omega L}{G + i\omega C}}$$

From the complex impedance values one can obtain various important parameters of a cable, e.g. its **attenuation α** :



Detailed numerical calculations of the microstrip capacitance are being done, and compared with the experimentally extracted values. Paper in preparation

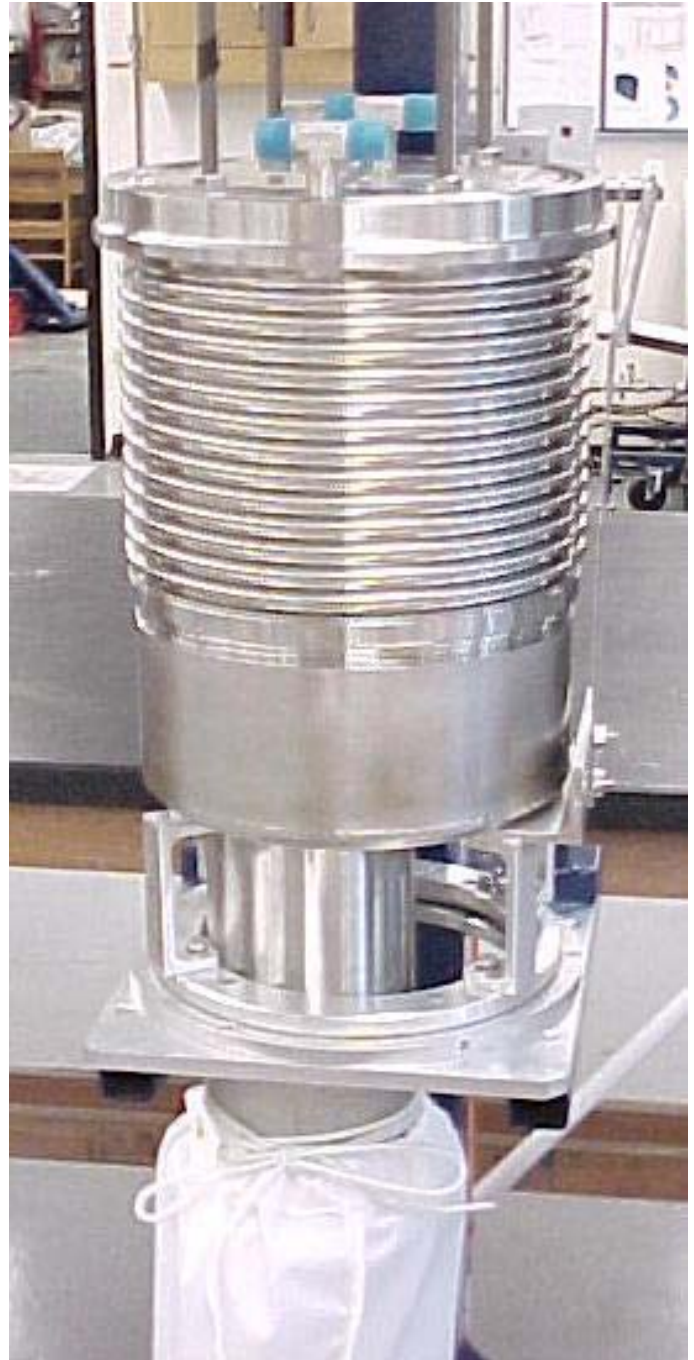
First Production Feedthroughs

Feedthrough FT0 completed on July 19th

FT0 Vacuum cable installation



FT0 before welds



First Production Feedthroughs

Welding of FT0 on July 19th



**Vacuum
cables
installation
on FT1,
which was
completed
on Oct 3rd**



QA/QC and TIS

- **Quality Assurance and Control** is critical to the success of the project
- **QA/QC Document Version 3** released on Sep 13 by the UVic team
- Procedures and document under **intense scrutiny** as the first feedthroughs are built
- Final **requirements from TIS** include a “**construction and non-conformity document**”, to be put together before the end of 2000

Pin Carrier Procurement

- P.O out in Jul 99 (joint with BNL)
- CERN procured vacuum grade steel used for first units: reception started in Oct 99
- Further deliveries delayed by Timken low inclusion steel procurement
- First units produced with Timken steel found to leak after cryogenics tests (BNL)
- Intense investigations of the problem by BNL and GSC/HSC/HCC. **Visit of HCC in LA** by T. Muller (BNL) and M. Lefebvre (UVic) on Aug 23rd 2000
- Timken steel found not to be suitable for hermetic seal cryogenics use
- Further units made with CERN and HCC procured vacuum grade steel **found to produce good units (Sep 2000)**
- **Plan for restart of production finalized early October 2000. HCC very helpful**
- **Five months were lost with the Timken steel problem. Pin carrier now on critical path**

Milestones and Schedule

Jan 2000 → Oct 2000

General

- **Production Readiness Review**
 - ◆ Passed in Jan 99
- **Leak Test Station and Electric Test Station**
 - ◆ Fully operational since Fall 98
- **Models and Prototypes**
 - ◆ Model done in 98
 - ◆ Prototype with dismountable flange done in 99
 - ◆ Insertion model done in Dec 99
 - ◆ TIS pressure test vessel → tested at CERN in March 00
 - ◆ Full prototype (FT-1) done in Jan 00
- **Welding**
 - ◆ Welding Plan completed in Dec 99
 - ◆ Agreement with TIS finalised in Dec 99
 - ◆ Qualification of welder → done in Feb00
- **Production of Feedthrough Units**
 - ◆ First feedthrough unit → (FT0) finalized in July 00
 - ◆ → FT1 finalized in Oct 00
 - ◆ → FT2 construction started
 - ◆ → Aim at average 3 units/month starting 1 Nov 00
 - ◆ Production of 25 units plus 3 spares by → Jul 01
 - ◆ Shipment and testing at CERN: → Feb 01 - Jul 01
 - ◆ Installation on cryostat ECC : → Sep 01 - Nov 01
 - ◆ Production of 25 units plus 3 spares by → Jun 02
 - ◆ Shipment and testing at CERN: → Feb 02 - Aug 02
 - ◆ Installation on cryostat ECA : → Aug 02 - Oct 02

Milestones and Schedule

Jan 2000 → Oct 2000

Mechanical Components

- **Low Inclusion Steel (Timken)**
 - ◆ → All received
- **Pin Carriers (GSC/HCC)**
 - ◆ P.O. out in Jun 99
 - ◆ Reception started in Oct 99 → to resume 1 Nov 00
 - ◆ → 26/550 received
- **Cold and Ambient Flanges (EBCO)**
- **Funnel Parts and Bolts Rings (SICOM)**
- **Seal and Cuff Rings for Bellows (SICOM)**
 - ◆ → All received
- **Funnel Assemblies (Spec. Mech.)**
 - ◆ → All received
- **Bellows Assemblies (BOA)**
 - ◆ Reception → 90% received
- **Other Components**
 - ◆ → Heater plates all manufactured
 - ◆ → Bellows braces all received
 - ◆ → All insulation (rohacel and mylar) cut and ready
 - ◆ → VCR Glands reception started

Milestones and Schedule

Jan 2000 → Oct 2000

Electrical Components

● Vacuum Cables

- ◆ RFQ reply from STC and FCI-Berg during fall 99
- ◆ STC cables passed qualification
- ◆ FCI-Berg cables qualification finalized Dec99 - Jan 00
- ◆ → Final contract awarded in Jan 00 to FCI-Berg
- ◆ → Reception started (588/1750 received and tested)

● Pigtail Cables (Axon via Orsay)

- ◆ MOU with Orsay signed in Dec 98
- ◆ Reception at Orsay started in Nov 99
- ◆ Reception in Victoria → (500/1635 received)

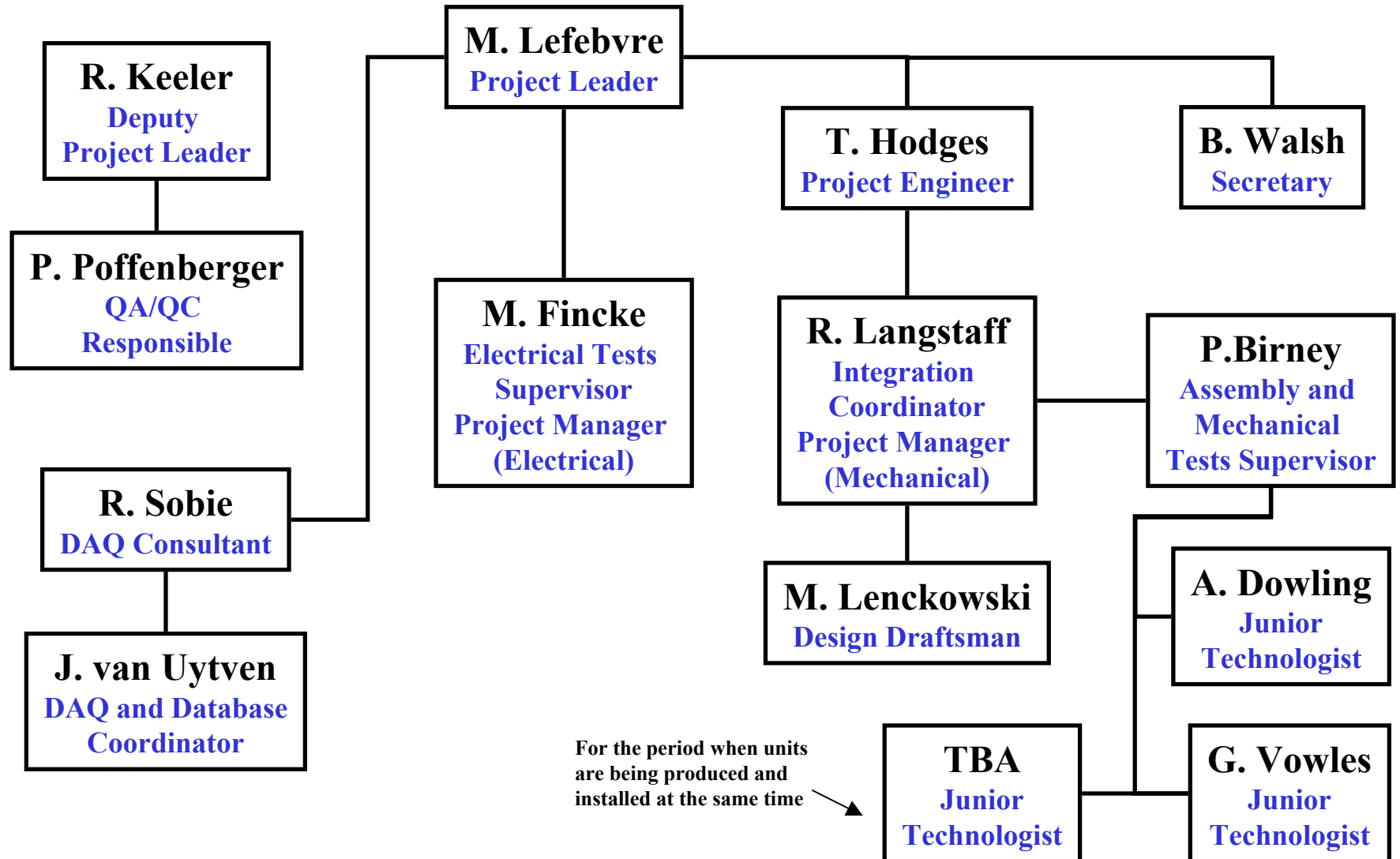
● Other Cables (Axon)

- ◆ RFQ reply received
- ◆ P.O. out in Jan 00
- ◆ → Reception started
- ◆ → all 40 LV vacuum cables received

● Heaters

- ◆ → Electrical design finalized
- ◆ → small PCB for heater connectors under construction

Budget and Management Organizational Chart



Budget and Management

Budget Summary

PBS	WBS	Description	Sep 00	MIG COST PROFILE								MIG	Sep 00			contingency \$CAN
			00-01	97-98	98-99	99-00	00-01	01-02	02-03	03-04		spent	commit	uncommit		
			\$CAN	\$CAN	\$CAN	\$CAN	\$CAN	\$CAN	\$CAN	\$CAN	\$CAN	%	%	%		
4	1	Endcap Signal Feedthroughs	\$455,694	\$224,375	\$261,707	\$503,577	\$1,594,824	\$1,174,668	\$192,783	\$28,793	\$3,980,726	36	50	14	\$432,753	
4.1	2	Project Setup	\$59,648	\$156,386	\$202,816	\$214,831	\$162,454	\$52,671	\$15,574	\$8,276	\$813,008	78	6	16	\$38,329	
4.1.1	3	Leak Test Setup	\$37,675	\$102,521	\$29,420	\$6,952	\$45,374	\$19,806	\$9,810	\$4,105	\$217,989	81	0	19	\$9,533	
4.1.2	3	Electric Test Setup	\$19,831	\$6,109	\$22,252	\$32,822	\$60,199	\$15,174	\$3,500	\$1,095	\$141,151	57	0	43	\$14,394	
4.1.3	3	Data Acquisition System	\$1,003	\$15,198	\$5,308	\$4,690	\$1,400	\$11,585	\$700	\$2,431	\$41,313	63	1	36	\$3,713	
4.1.4	3	FT Assembly Tools	\$0	\$0	\$10,135	\$591	\$44,724	\$840	\$211	\$0	\$56,500	19	76	5	\$7,144	
4.1.5	3	FT Prototypes	-\$2,636	\$32,558	\$135,094	\$163,028	\$4,057	\$101	\$0	\$218	\$335,055	98	2	0	\$1,077	
4.1.6	3	Misc Project Setup Items	\$3,775	\$0	\$607	\$6,748	\$6,700	\$5,165	\$1,353	\$427	\$21,000	53	0	47	\$2,467	
4.2	2	FT Series Assemblies	\$333,154	\$0	\$0	\$142,211	\$1,274,870	\$913,497	\$0	\$0	\$2,330,579	20	69	11	\$350,367	
4.2.1	3	Mechanical Components	\$120,328	\$0	\$0	\$141,714	\$421,821	\$490,111	\$0	\$0	\$1,053,647	25	63	12	\$129,310	
4.2.2	3	Electrical Components	\$212,153	\$0	\$0	\$399	\$832,049	\$362,483	\$0	\$0	\$1,194,932	18	77	5	\$203,318	
4.2.3	3	Shipping Crates	\$672	\$0	\$0	\$98	\$21,000	\$60,902	\$0	\$0	\$82,000	1	21	78	\$17,739	
4.3	2	Test Cryostat Signal FT	\$0	\$58,428	\$0	\$0	\$0	\$0	\$0	\$0	\$58,428	100	0	0	\$0	
4.4	2	Manpower	\$62,892	\$9,561	\$58,891	\$146,534	\$157,500	\$208,500	\$177,209	\$20,517	\$778,712	36	42	22	\$44,057	
4.4.1	3	Salaries and Benefits	\$57,253	\$9,561	\$55,092	\$129,328	\$131,000	\$185,000	\$156,268	\$11,799	\$678,048	37	48	15	\$26,341	
4.4.2	3	Consultation and Travel	\$2,505	\$0	\$1,016	\$17,206	\$19,500	\$18,500	\$18,225	\$8,718	\$83,164	25	4	71	\$14,821	
4.4.3	3	Other	\$3,134	\$0	\$2,784	\$0	\$7,000	\$5,000	\$2,716	\$0	\$17,500	34	0	66	\$2,896	

Contingencies total \$433k and are dominated by exchange rates:

+15% on 1.52 \$CAN/\$US (pin carriers and vacuum cables)

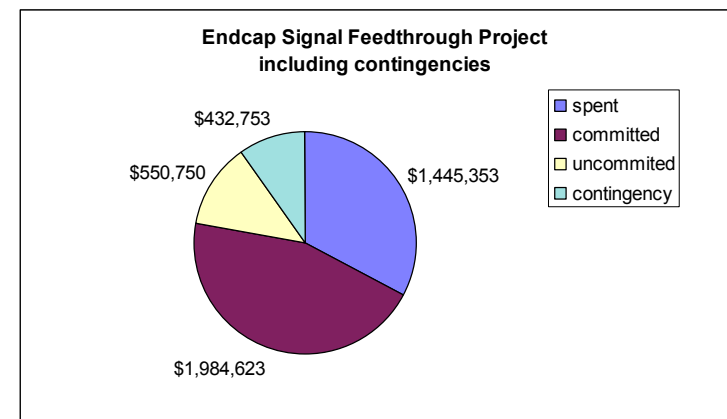
+25% on 0.200 \$CAN/FF (pigtailed)

+15% on 0.860 \$CAN/CHF (orbital cutter contribution)

The budget total net of contingencies is \$3.98M

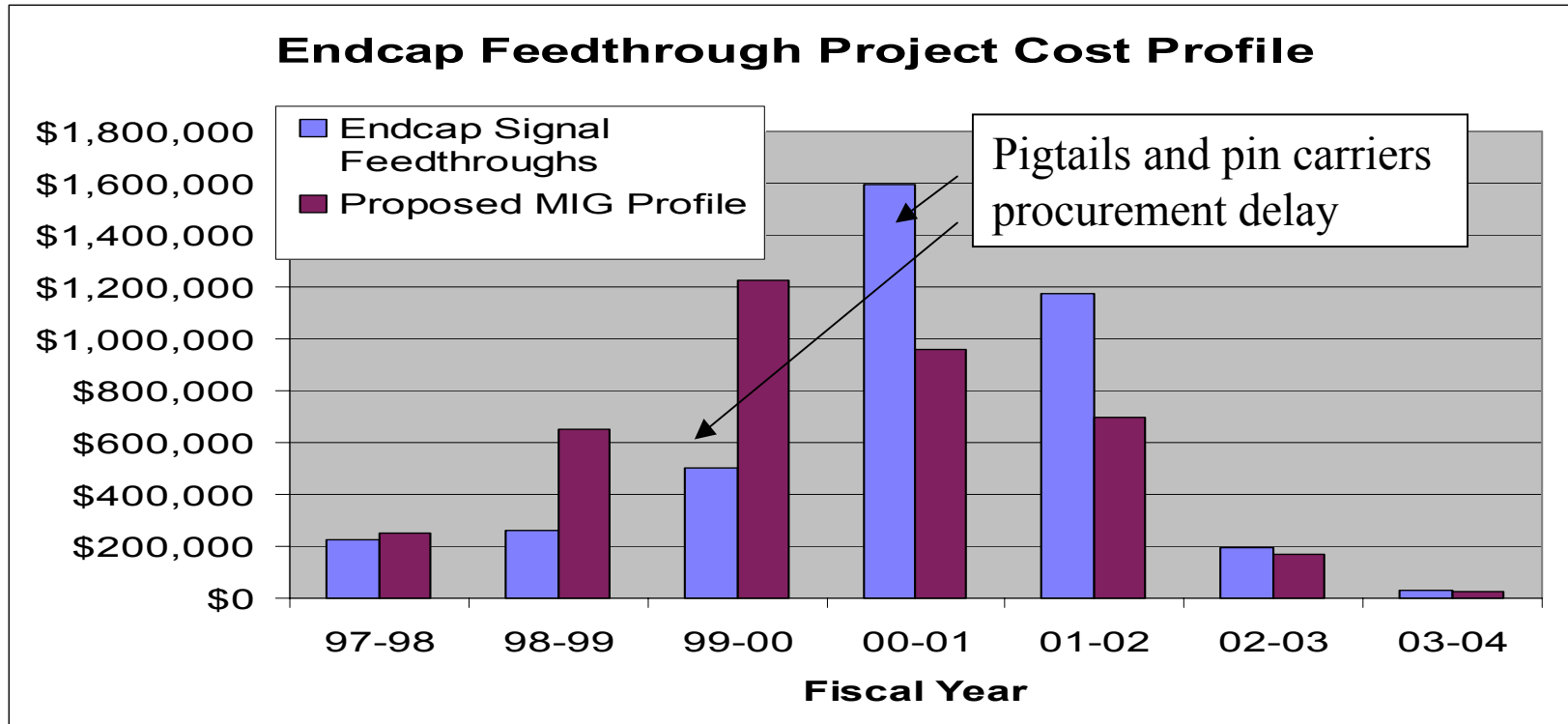
36% of which has been spent (Sep 00)

50% of which has been committed (Sep 00)



Budget and Management

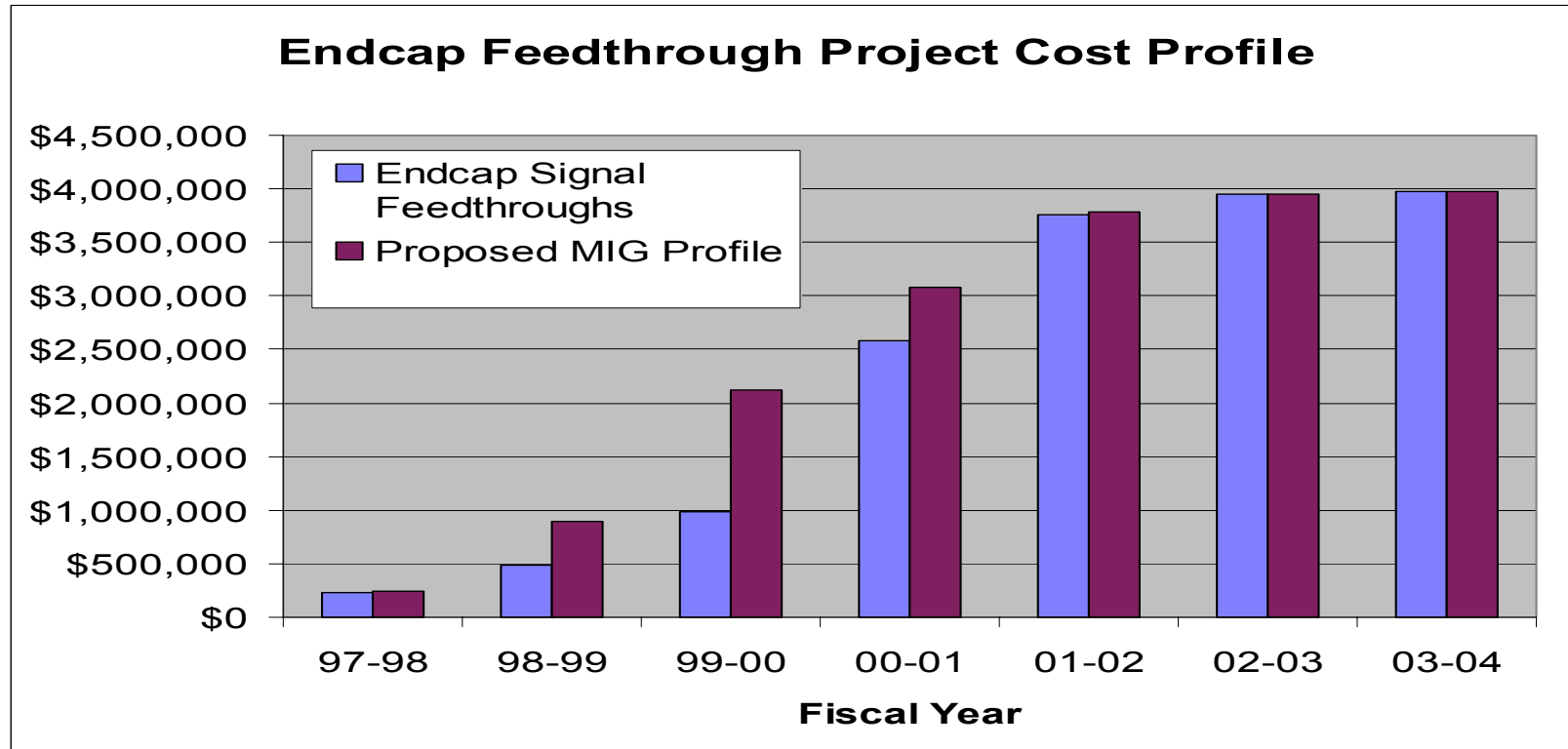
Budget Profile



	97-98	98-99	99-00	00-01	01-02	02-03	03-04	Total
Sep-00	\$CAN	\$CAN	\$CAN	\$CAN	\$CAN	\$CAN	\$CAN	\$CAN
Budget	\$224,375	\$261,707	\$503,577	\$1,594,824	\$1,174,668	\$192,783	\$28,793	\$3,980,726
MIG spent	\$224,375	\$261,707	\$503,577	\$455,694	\$0	\$0	\$0	\$1,445,353
Proposed MIG Profile	\$249,000	\$650,000	\$1,226,880	\$960,000	\$700,000	\$170,000	\$24,846	\$3,980,726

Budget and Management

Integrated Budget Profile



	97-98	98-99	99-00	00-01	01-02	02-03	03-04	Total
Sep-00	\$CAN	\$CAN	\$CAN	\$CAN	\$CAN	\$CAN	\$CAN	\$CAN
Budget	\$224,375	\$486,082	\$989,659	\$2,584,483	\$3,759,151	\$3,951,933	\$3,980,726	\$3,980,726
MIG spent	\$224,375	\$486,082	\$989,659	\$1,445,353	\$1,445,353	\$1,445,353	\$1,445,353	\$1,445,353
Proposed MIG Profile	\$249,000	\$899,000	\$2,125,880	\$3,085,880	\$3,785,880	\$3,955,880	\$3,980,726	\$3,980,726

Budget and Management

Series Assemblies Details

PBS	WBS	Description	MIG COST PROFILE								spent %	commit %	uncommit %	contingency \$CAN
			97-98 \$CAN	98-99 \$CAN	99-00 \$CAN	00-01 \$CAN	01-02 \$CAN	02-03 \$CAN	03-04 \$CAN	MIG \$CAN				
4	1	Endcap Signal Feedthroughs	\$224,375	\$261,707	\$503,577	\$1,594,824	\$1,174,668	\$192,783	\$28,793	\$3,980,726	36	50	14	\$432,753
4.1	2	Project Setup	\$156,386	\$202,816	\$214,831	\$162,454	\$52,671	\$15,574	\$8,276	\$813,008	78	6	16	\$38,329
4.2	2	FT Series Assemblies	\$0	\$0	\$142,211	\$1,274,870	\$913,497	\$0	\$0	\$2,330,579	20	69	11	\$350,367
4.2.1	3	Mechanical Components	\$0	\$0	\$141,714	\$421,821	\$490,111	\$0	\$0	\$1,053,647	25	63	12	\$129,310
4.2.1.0	4	Low Inclusion Steel	\$0	\$0	\$36,585	\$27,699	\$0	\$0	\$0	\$64,284	100	0	0	\$0
4.2.1.1	4	Pin Carriers	\$0	\$0	\$37,019	\$175,000	\$469,611	\$0	\$0	\$681,630	4	84	12	\$106,130
4.2.1.2	4	Warm Flanges	\$0	\$0	\$0	\$20,818	\$0	\$0	\$0	\$20,818	100	0	0	\$0
4.2.1.3	4	Cold Flanges	\$0	\$0	\$0	\$21,235	\$0	\$0	\$0	\$21,235	100	0	0	\$0
4.2.1.4	4	Bellow Assemblies	\$0	\$0	\$20,564	\$102,369	\$0	\$0	\$0	\$122,932	53	47	0	\$8,662
4.2.1.5	4	Bolt Flanges	\$0	\$0	\$18,370	\$0	\$0	\$0	\$0	\$18,370	100	0	0	\$0
4.2.1.6	4	Funnel Assemblies	\$0	\$0	\$12,813	\$52,160	\$0	\$0	\$0	\$64,973	42	58	0	\$3,773
4.2.1.7	4	Pipe Fittings	\$0	\$0	\$0	\$500	\$500	\$0	\$0	\$1,000	0	10	90	\$235
4.2.1.8	4	RF Gasket	\$0	\$0	\$0	\$1,200	\$0	\$0	\$0	\$1,200	0	0	100	\$300
4.2.1.9	4	Insulation	\$0	\$0	\$4,161	\$839	\$0	\$0	\$0	\$5,000	83	0	17	\$210
4.2.1.10	4	Welds	\$0	\$0	\$0	\$20,000	\$20,000	\$0	\$0	\$40,000	0	0	100	\$10,000
4.2.1.11	4	CF Flanges	\$0	\$0	\$12,203	\$0	\$0	\$0	\$0	\$12,203	100	0	0	\$0
4.2.2	3	Electrical Components	\$0	\$0	\$399	\$832,049	\$362,483	\$0	\$0	\$1,194,932	18	77	5	\$203,318
4.2.2.1	4	Pig Tail Cables	\$0	\$0	\$192	\$200,000	\$299,803	\$0	\$0	\$499,995	0	100	0	\$124,866
4.2.2.2	4	Vacuum Cables	\$0	\$0	\$0	\$510,576	\$0	\$0	\$0	\$510,576	33	67	0	\$51,500
4.2.2.3	4	Low Voltage Pigtail Cables	\$0	\$0	\$0	\$30,691	\$30,691	\$0	\$0	\$61,382	48	49	3	\$4,977
4.2.2.4	4	Low Voltage Vacuum Cables	\$0	\$0	\$0	\$19,490	\$19,490	\$0	\$0	\$38,980	5	90	5	\$5,750
4.2.2.5	4	Heaters	\$0	\$0	\$207	\$31,793	\$0	\$0	\$0	\$32,000	1	20	79	\$7,245
4.2.2.6	4	Extra HEC Pigtails	\$0	\$0	\$0	\$12,499	\$12,499	\$0	\$0	\$24,998	46	46	8	\$2,230
4.2.2.7	4	Temperature Probes	\$0	\$0	\$0	\$27,000	\$0	\$0	\$0	\$27,000	0	0	100	\$6,750
4.2.3	3	Shipping Crates	\$0	\$0	\$98	\$21,000	\$60,902	\$0	\$0	\$82,000	1	21	78	\$17,739
4.3	2	Test Cryostat Signal FT	\$58,428	\$0	\$0	\$0	\$0	\$0	\$0	\$58,428	100	0	0	\$0
4.4	2	Manpower	\$9,561	\$58,891	\$146,534	\$157,500	\$208,500	\$177,209	\$20,517	\$778,712	36	42	22	\$44,057
4.4.1	3	Salaries and Benefits	\$9,561	\$55,092	\$129,328	\$131,000	\$185,000	\$156,268	\$11,799	\$678,048	37	48	15	\$26,341
4.4.2	3	Consultation and Travel	\$0	\$1,016	\$17,206	\$19,500	\$18,500	\$18,225	\$8,718	\$83,164	25	4	71	\$14,821
4.4.3	3	Other	\$0	\$2,784	\$0	\$7,000	\$5,000	\$2,716	\$0	\$17,500	34	0	66	\$2,896

Budget and Management Responsibilities

- **Design**
- **Fabrication**
 - ◆ **Signal Pigtails purchased from Orsay**
- **Commissioning**
- **Transport**
- **Reception**
 - ◆ **Electrical and ambient vacuum testing**
 - ◆ **Leak tester provided by ATLAS CERN**
- **Electrical tests after installation**
- **Assistance during installation**
 - ◆ **Up to SF50k towards the cost of an orbital cutter**
 - ◆ **Assistance during welding on the cryostat**
 - ◆ **Assistance for leak testing during/after installation**

- **Still under discussion**
 - ◆ **Who covers cost of T probes**
 - ◆ **Manpower to connect warm cables to ambient flange**

Conclusions

Endcap Signal Feedthrough Project

- **Crucial component of ATLAS LAr**
- **Complex and manpower intensive**
- **Production has started**
 - ◆ **First unit constructed in July 00**
 - ◆ **Proceeding cautiously with emphasis on QA/QC**
- **Extensive QC programme further developed**
- **All major purchase orders out**
- **All components (except pigtails, pin carriers and a few cables) likely to be in hand by the end of FY 00-01**
- **Production rate still in line with cryostat schedule**
 - ◆ **Pin carrier procurement on critical path**
 - ◆ **To be reassessed when pin carrier procurement reaches full rate**
- **Budget within the allocated MIG**
 - ◆ **Built-in contingencies**
 - ◆ **Purchase of FF for pigtails under investigation**
 - ◆ **Requires close monitoring**

Budget and Management

Project Setup Details

PBS	WBS	Description	MIG COST PROFILE							MIG	spent %	commit %	uncommit %	contingency \$CAN
			97-98 \$CAN	98-99 \$CAN	99-00 \$CAN	00-01 \$CAN	01-02 \$CAN	02-03 \$CAN	03-04 \$CAN					
4	1	Endcap Signal Feedthroughs	\$224,375	\$261,707	\$503,577	\$1,594,824	\$1,174,668	\$192,783	\$28,793	\$3,980,726	36	50	14	\$432,753
4.1	2	Project Setup	\$156,386	\$202,816	\$214,831	\$162,454	\$52,671	\$15,574	\$8,276	\$813,008	78	6	16	\$38,329
4.1.1	3	Leak Test Setup	\$102,521	\$29,420	\$6,952	\$45,374	\$19,806	\$9,810	\$4,105	\$217,989	81	0	19	\$9,533
4.1.1.1	4	He Leak Tester	\$29,677	\$4,368	\$91	\$35,000	\$2,500	\$2,310	\$1,055	\$75,000	91	0	9	\$1,606
4.1.1.2	4	RGA	\$17,500	\$0	\$0	\$0	\$0	\$0	\$0	\$17,500	100	0	0	\$0
4.1.1.3	4	Calibrated He leaks	\$2,265	\$1,130	\$0	\$1,674	\$0	\$0	\$0	\$5,069	100	0	0	\$0
4.1.1.4	4	Cold Cathode / Pirani Gauges	\$6,500	\$0	\$5	\$0	\$0	\$0	\$0	\$6,505	100	0	0	\$0
4.1.1.5	4	Scroll Pump	\$0	\$8,219	\$0	\$0	\$8,219	\$0	\$0	\$16,438	50	0	50	\$1,233
4.1.1.6	4	Cryo Cooler	\$13,637	\$0	\$0	\$0	\$0	\$0	\$0	\$13,637	100	0	0	\$0
4.1.1.7	4	Ion Pump Parts	\$1,654	\$0	\$0	\$0	\$0	\$0	\$0	\$1,654	100	0	0	\$0
4.1.1.8	4	Temperature Probes	\$0	\$4,334	\$1,383	\$500	\$1,000	\$500	\$284	\$8,000	71	0	29	\$571
4.1.1.9	4	Valves	\$15,933	\$489	\$0	\$1,000	\$1,000	\$1,000	\$578	\$20,000	82	0	18	\$895
4.1.1.10	4	Vacuum Parts	\$6,891	\$555	\$3,109	\$3,000	\$3,000	\$3,000	\$445	\$20,000	57	0	43	\$2,133
4.1.1.11	4	Misc Hardware	\$1,215	\$8,403	\$346	\$2,000	\$2,000	\$1,000	\$36	\$15,000	67	0	33	\$1,223
4.1.1.12	4	Temperature Cycling Setup	\$1,581	\$571	\$162	\$200	\$87	\$0	\$0	\$2,600	89	0	11	\$72
4.1.1.13	4	Design Station	\$5,670	\$915	\$0	\$0	\$0	\$0	\$0	\$6,585	100	0	0	\$0
4.1.1.14	4	Liquid Nitrogen	\$0	\$436	\$1,857	\$2,000	\$2,000	\$2,000	\$1,707	\$10,000	28	0	72	\$1,801
4.1.2	3	Electric Test Setup	\$6,109	\$22,252	\$32,822	\$60,199	\$15,174	\$3,500	\$1,095	\$141,151	57	0	43	\$14,394
4.1.2.1	4	DC Test Setup	\$0	\$14,058	\$1,746	\$8,043	\$1,000	\$1,000	\$154	\$26,000	61	0	39	\$2,102
4.1.2.2	4	Transient Test Setup	\$263	\$7,778	\$12,509	\$13,500	\$12,174	\$1,500	\$580	\$48,304	68	0	32	\$3,646
4.1.2.3	4	Pig Tail Cables for tests	\$5,846	\$0	\$0	\$6,676	\$0	\$0	\$0	\$12,522	100	0	0	\$0
4.1.2.4	4	Misc Hardware	\$0	\$417	\$3,222	\$2,000	\$2,000	\$1,000	\$361	\$9,000	49	0	51	\$1,151
4.1.2.5	4	Pig Tail Loop Cables for Tests	\$0	\$0	\$15,325	\$0	\$0	\$0	\$0	\$15,325	100	0	0	\$0
4.1.2.6	4	Digital Scope	\$0	\$0	\$20	\$29,980	\$0	\$0	\$0	\$30,000	0	0	100	\$7,495
4.1.3	3	Data Acquisition System	\$15,198	\$5,308	\$4,690	\$1,400	\$11,585	\$700	\$2,431	\$41,313	63	1	36	\$3,713
4.1.3.1	4	NT Server PC	\$5,762	\$0	\$0	\$0	\$5,838	\$0	\$0	\$11,600	50	0	50	\$1,460
4.1.3.2	4	NT Client PC for DAQ	\$3,883	\$0	\$2,469	\$0	\$0	\$0	\$0	\$6,352	100	0	0	\$0
4.1.3.3	4	NT Licences	\$394	\$0	\$0	\$0	\$0	\$0	\$394	\$394	100	0	0	\$0
4.1.3.4	4	GPIB Interface	\$787	\$0	\$1,166	\$0	\$1,047	\$0	\$0	\$3,000	65	0	35	\$262
4.1.3.5	4	LabView Licenses	\$3,853	\$205	\$0	\$900	\$0	\$400	\$142	\$5,500	89	0	11	\$146
4.1.3.6	4	Colour Printer	\$489	\$0	\$0	\$0	\$0	\$0	\$0	\$489	100	0	0	\$0
4.1.3.7	4	Printer	\$0	\$0	\$0	\$0	\$300	\$0	\$0	\$300	0	0	100	\$75
4.1.3.8	4	Misc Hard/Software and Services	\$31	\$424	\$1,055	\$500	\$400	\$300	\$290	\$3,000	55	14	30	\$271
4.1.3.9	4	NT Client PC for Controls	\$0	\$4,679	\$0	\$0	\$0	\$0	\$0	\$4,679	100	0	0	\$0
4.1.3.10	4	CAMAC controller	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	0	0	100	\$0
4.1.3.11	4	NT Client PC for CERN	\$29,677	\$0	\$0	\$0	\$4,000	\$0	\$2,000	\$6,000	0	0	100	\$1,500
4.1.4	3	FT Assembly Tools	\$0	\$10,135	\$591	\$44,724	\$840	\$211	\$0	\$56,500	19	76	5	\$7,144
4.1.4.1	4	Assembly Jigs	\$0	\$2,234	\$226	\$1,000	\$540	\$0	\$0	\$4,000	62	0	38	\$385
4.1.4.2	4	Welding Station	\$0	\$7,900	\$289	\$300	\$300	\$211	\$0	\$9,000	91	0	9	\$203
4.1.4.3	4	Crane	\$0	\$0	\$76	\$424	\$0	\$0	\$0	\$500	15	0	85	\$106
4.1.4.4	4	Orbital Cutter	\$0	\$0	\$0	\$43,000	\$0	\$0	\$0	\$43,000	0	100	0	\$6,450
4.1.5	3	FT Prototypes	\$32,558	\$135,094	\$163,028	\$4,057	\$101	\$0	\$218	\$335,055	98	2	0	\$1,077
4.1.5.1	4	Model FT	\$2,289	\$775	\$0	\$0	\$0	\$0	\$0	\$3,064	100	0	0	\$0
4.1.5.2	4	Weld Test Flanges and Pin Carriers	\$11,815	\$4,297	\$8,650	\$909	\$0	\$0	\$217	\$25,889	98	0	2	\$143
4.1.5.3	4	Glass Pin Carriers	\$0	\$50,818	\$0	-\$2,147	\$0	\$0	\$0	\$48,671	100	0	0	\$0
4.1.5.4	4	Ceramic Pin Carriers	\$0	\$63,446	\$0	-\$2,147	\$0	\$0	\$0	\$61,299	100	0	0	\$0
4.1.5.5	4	Warm Flanges	\$0	\$2,497	\$221	\$0	\$0	\$0	\$0	\$2,718	100	0	0	\$0
4.1.5.6	4	Cold Flanges	\$0	\$2,304	\$246	\$0	\$0	\$0	\$0	\$2,550	100	0	0	\$0
4.1.5.7	4	Bellows Assemblies	\$0	\$3,654	\$10,540	\$5,510	\$0	\$0	\$0	\$19,704	72	28	0	\$826
4.1.5.8	4	Bolt Flanges	\$0	\$0	\$246	\$0	\$0	\$0	\$0	\$246	100	0	0	\$0
4.1.5.9	4	Funnel Assemblies	\$0	\$2,663	\$2,497	\$0	\$0	\$0	\$0	\$5,160	100	0	0	\$0
4.1.5.10	4	Vacuum Cables	\$18,453	\$0	\$120,470	\$359	\$0	\$0	\$0	\$139,282	100	0	0	\$0
4.1.5.11	4	Low Voltage Vacuum cables	\$0	\$4,086	\$0	\$0	\$0	\$0	\$0	\$4,086	100	0	0	\$0
4.1.5.12	4	Low Voltage Pigtails	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	100	0	0	\$0
4.1.5.13	4	Pipe Fittings	\$0	\$554	\$0	\$0	\$0	\$0	\$0	\$554	100	0	0	\$0
4.1.5.14	4	Pigtails	\$0	\$0	\$17,934	\$397	\$0	\$0	\$0	\$18,331	100	0	0	\$0
4.1.5.15	4	Insulation	\$0	\$0	\$2,225	\$1,175	\$101	\$0	\$0	\$3,500	73	24	3	\$108
4.1.6	3	Misc Project Setup Items	\$0	\$607	\$6,748	\$6,700	\$5,165	\$1,353	\$427	\$21,000	53	0	47	\$2,467
4.2	2	FT Series Assemblies	\$0	\$0	\$142,211	\$1,274,870	\$913,497	\$0	\$0	\$2,330,579	20	69	11	\$350,367
4.3	2	Test Cryostat Signal FT	\$58,428	\$0	\$0	\$0	\$0	\$0	\$0	\$58,428	100	0	0	\$0
4.3.1	3	Pin Carriers	\$56,960	\$0	\$0	\$0	\$0	\$0	\$0	\$56,960	100	0	0	\$0
4.3.4	3	Bolt Flanges	\$1,468	\$0	\$0	\$0	\$0	\$0	\$0	\$1,468	100	0	0	\$0
4.4	2	Manpower	\$9,561	\$58,891	\$146,534	\$157,500	\$208,500	\$177,209	\$20,517	\$778,712	36	42	22	\$44,057