Advanced Virgo

preliminary

Cost Plan and Project Execution Plan

VIR–043A–07

The Virgo Collaboration

edited by

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Contents

1 Introduction

This document has been written together with the *Advanced Virgo Conceptual Design* and is addressed to the EGO STAC and Council. The main purposes of the document are:

- to give an first estimate of the costs of the Advanced Virgo (AdV) upgrade: the figures reported are based on the current information. The costs for some subsystems have been analized with more details on the base of the existing experience, others will need further refinement. At this early stage we decided to add a 30% contingency as a safety factor for extra costs associated to open design options, unexpected expenses and/or uncorrect estimates;
- to draft the AdV organization for the next phase: after the delivery of the Conceptual Design, the Virgo Collaboration plans to prepare the AdV Technical Design, to be delivered by the end of 2009. In this document we present a preliminary scheme of the organization needed to face this new phase.

The use of the word *preliminary* in the title of this document means that:

- we expect the cost model to be refined in the next months as the activity of the subsystems starts and gets momentum;
- we foresee that the work breakdown structure (WBS) proposed in sec. 3 might be adjusted;
- we expect to harmonize the proposed structure with the decisions taken by the funding agencies on the overall project organization.

2 AdV evolution

The realization of AdV is made of 4 steps:

1. The realization of the Conceptual Design and Project Execution Plan (2006-2007).
2. The setting up of the WBS and the realization of a Technical Design (2008-2009).
3. The completion of R&D and the procurement of the parts for the construction (2009-2011).
4. The assembly and integration (2011-2012).

During phase 4 we expect to install all the main new parts of the detector. We are studying the possibility not to install the signal recycling (SR) mirror and have a first commissioning phase of the detector without SR. This would allow to learn the effects of high power in a simpler optical configuration. A first science run should follow. Afterwards we would install the SR mirror and commission the dual-recycled interferometer. The possibility to upgrade the detector with new parts that have become technically ready during this break will be studied.

To complete step 1 the VIRGO Collaboration set up four working groups and appointed an AdV Coordinator, whose mandate has ended with the release of these documents. We have considered the WGs structure no more adequate to perform the following steps. The Collaboration decided to:

- dismiss the working groups;
- appoint again a coordinator of the AdV activities with the mandate of managing the phase 2;
- start assigning the subsystems and tasks responsibilities to the labs/EGO;

2.1 AdV phase 2

For phase 2 we propose to organize the activity as follows:

- the project is divided into *subsystems* (the ones indicated in sec. 3). The subsystems do not correspond necessarily to single-laboratory assignments but are transversal. Each subsystem is managed by a *subsystem manager* (SM). The SMs are responsible for providing a subsystem execution plan, with clear milestones and deliverables;
- each subsystem is divided into *tasks*. In most cases a task coincide with the construction of a piece of the detector. It is assigned to a single lab and managed by a *task manager* (TM). The work of the TMs is coordinated by the SM, who ensures the coherence of the subsystem design;
- the AdV coordinator follows the activities of all the subsystems, makes sure that the interfaced subsystems communicate and ensures the coherence of the whole design. Beside that, he/she coordinates the AdV R&D activity

The SMs should be appointed soon. Their mandate is:

- to collect around them the people who have the expertise to contribute to the realization of the subsystem;
- to make the detailed list of the tasks;
- to discuss the list of the task managers with the AdV coordinator and the Spokesman;
- to write the detailed *subsystem plan* with milestones and deliverables;
- to identify the interfaces with the other subsystems.

2.2 The first project review

The AdV phase two should last 2 years and will end with the completion of the *AdV technical Design*. By mid 2008 each SM must present the subsystem plan and the list of task managers must be defined. In fall 2008 the 1^{st} AdV review must be held with the aim of:

- review the subsystems plans and activities;
- take a final decision on the open options with the biggest impact on the design.

3 Work Breakdown Structure

The AdV activities are covered by the following subsystems:

- **Vacuum (VAC)**
- **Superattenuators (SAT)**
- **Payload (PAY)**
- **Mirrors (MIR)**
- **Thermal compensation (TCS)**
- **Laser (LAS)**
- **Injection system (INJ)**
- **Detection (DET)**
- **Optical simulation and design (OSD)**
- **Interferometer sensing and control (ISC)**
- **Data Acquisition (DAQ)**
- **Data Management (DAM)**
- **Infrastucture modifications for environmental noise reduction (IME)**

3.1 VAC

The **Vacuum** subsystem (VAC) concerns all the modifications to the vacuum pipes and towers. The main tasks of VAC will be: the replacement of the vacuum links in the central area (compliant with the larger beam), the realization of the vacuum chamber for the new signal recycling tower and the installation of the clean air flux in each tower.

3.2 SAT

The **Superattenuators** subsystem (SAT) concerns all the modifications to the existing SAs and the construction of the SR one. The main task of SAT are: the construction of the superattenuator for the signal recycling mirror, the upgrade of the short towers, the change of the inverted pendulum legs, the implementation of the tilt control and all the modifications to the inertial damping, the upgrade of the filter 0 on the long towers.

3.3 PAY

The **Payload** subsystem (PAY) concerns the realization of the SA payload (marionette-MRM-test mass-RM). The main tasks of PAY are: the design and realization of the new marionette, of the marionette reference mass and of the new reference mass, the selection and realization of the new test mass actuators, the realization of the monolithic payload, the sensing/actuation for local controls.

3.4 MIR

The **Mirrors** subsystem (MIR) concerns the procurement and preparation of the AdV test masses and spares. The main tasks of MIR are: the realization of the substrates (including spares) and the coatings with the best available optical and mechanical features. A related task is the study of the mirror charging and of possible solutions.

3.5 TCS

The **Thermal compensation** subsystem (TCS) concerns the design and installation of the new thermal compensation system. The scheme to be used for AdV is being studied.

3.6 LAS

The **Laser** subsystem (LAS) concerns the installation of the new high power laser. The main tasks of LAS are: the realization of the master laser and of the 20 W injection-locked laser, the installation of the 200 W amplifier after the design of matching optics, the design and construction of the pre-mode cleaner and of the power stabilization electronics. If the fiber option is selected, fiber amplifier is to be installed in place of the solid-state one.

3.7 INJ

The **Injection** subsystem (INJ) concerns all the modifications of the injection system to make it compliant with AdV. The main tasks of INJ are: the design of the optical layout downstream the laser bench, the input optics (EOM and RF modulation, Faraday isolator, polarizers, mechanics), the injection bench (mechanics, mode matching telescope, adaptive mode matching system), input mode cleaner (optics and mechanics).

3.8 DET

The **Detection** subsystem (DET) concerns all the modifications to the detection benches, with the related optics, and to the photodiodes. The main tasks of DET are: the photodiodes and their acoustic isolation, the new output mode cleaner, the output optics.

3.9 OSD

The **Optical simulation and design** subsystem (OSD) concerns the finalization of the optical scheme. The main tasks of OSD are: the definition of the critical optical design parameters (cavity finesse, SR mirror characteristics, mirror wedges,...) and the coordination and steering of the various simulation efforts.

3.10 ISC

The **Interferometer sensing and control** subsystem (ISC) concerns the preparation of the complete control strategy (locking, alignment, suspension control). The main tasks of ISC are: the preparation of the locking and alignment strategy, the noise budget of the predictable control noise. Moreover, ISC must give inputs for the deisgn of the control electronics and the actuators.

3.11 DAQ

The **Data Acquisition** subsystem (DAQ) concerns the electronics and software related to the control of the ITF. The main tasks of DAQ all the modifications to the electronics, the replacement of obsolete systems (including workstations and computer networks), the upgrade of control loops (hardware, software and algorithms), automation, timing, data conversion, environment monitoring and control. Front end electronics can be excluded in all cases where a strong interaction with a given external system is required. DAQ system shall dictate specifications for any piece of hardware and software involved in the operation of AdV.

3.12 DAM

The **Data Management** subsystem (DAM) concerns data storage, distribution, on-line and in-time computing. The main tasks of DAM are the storage farm, the data transfer, the data access, the hardware and software infrastructure for data analysis including the on-line processing and the in-time computing applied to noise hunting and event searches.

3.13 IME

The **Infrastucture modifications for environmental noise reduction** subsystem (IME) concerns all the hard works aimed to reduce the level of anthropogenic noise into the main and end buildings. The main tasks of IME will be: the replacement of the machines with more silent ones and, if needed, their displacement out of the experimental halls.

4 Subsystem cost estimates

4.1 VAC cost

In the following table the estimated costs for VAC are summarized[1]:

Item	Cost (kE)
Links	650
SR vacuum	310
VAC TOTAL	**960**

In the following tables the details for the VAC items are summarized:

Links:

Item	Number	Cost (kE)
500 mm vacuum valves	4+1	180
600 mm links (incl. Brewsters)	6	170
1 m tower flanges with 500/600 mm ports	12	180
Helicoflex metal gaskets	12(1 m)+18(500/600 mm)+sp.	55
mod. of ovens wall apertures..		20
Improved tower clamping to ground		10
tools for heavy components handling		20
baffles	30	10
supports and tools for baffles installation		5
total links		650

SR tower:

Item	Cost (kE)
3 rings	110
separating roof	180
scaffolding	20
total SR tower	310

[1] The cost for the clean air flux installation is missing.

4.2 SAT Cost

In the following table the foreseen costs for the SAT subsystem are summarized:

Item	Number	**Tot. Cost (kE)**
New IP legs	6	120
PZTs for 1 SA	9	180
Filter 0 crossbar	9	90
Tiltmeters for 1 SA	9	110
HV cables	9	25
additional filter for short SA	3	25
SR SA		555
SAT TOTAL		**1105**

In the following table the cost for the new SR SA is detailed:

Item	**Quantity**	**Tot. Cost (kE)**
New IP		25
Safety structure		15
Standard filters	6	55
Suspension wires		5
Blades		8
Stepping motors	12	18
PZT	3	20
Tiltmeters+cables	2	15
Vert. hoist mech.		4
Tools		5
Sensors/actuators for ID		80
Electronics		120
UHV cables		70
Payload		115
SR SA total		**555**

4.3 PAY Cost

In the following table the foreseen costs for the PAY subsystem are summarized[2]:

Item	Unity cost (kE)	Number	Tot. Cost (kE)
MRM	40	6	240
MRM ass. structure	30	1	30
Marionette	30	6	180
RM	45	6	270
PAY TOTAL			**720**

In the following tables the costs for the different PAY parts are detailed:

MRM:

Item	Quantity	Tot. Cost (kE)
Assembly structure		*30*
MRM mechanics		20
Stepping motors	2	4
Coil-magnet pairs	4	8
UHV cables		2
F7 modifications		6
MRM total		40+30

New marionette:

Item	Quantity	Tot. Cost (kE)
Material		10
Machining		10
Motors+mechanics		10
Marionette total		30

New reference mass:

[2] The cost for the new payloads is calculated here for the six existing long SA. The payload for the SR SA is accounted for in the SAT cost.

Item	**Quantity**	**Tot.Cost (kE)**
Material		20
Machining		10
Coils support		2.5
Coils wire		5
Coils holder		2.5
Coils machining		5
RM total		45

4.4 MIR Cost

The expected costs for MIR are presented considering different options for the polishing and the corrective coating and different numbers for the spares:

- **spares:** the 4-4-2 option foresees to have 4 input mirrors, 4 end mirrors and 2 beam splitters. The 6-6-3 one foresees to have 6 input mirrors, 6 end mirrors and 3 beam splitters;
- **polishing:** the cost is different if the *best polishing* is required;
- **corrective coating:** the possibility to have corrective coating is taken into account.

Item	**Cost for 4-4-2 (kE)**	**Cost for 6-6-4 (kE)**
Cheaper polishing and corr. coating	3500	4500
Best polishing and no corr. coating	3750	5000
Best polishing and corr. coating	*4100*	5350
MIR TOTAL	**4100**	

In the cost summary of sec. 6 we consider the 4-4-2 option with best polishing and corrective coating. This might be subject to a different evaluation in the following months and buying more spares could be necessary. If the 60 Kg option is chosen the cost for the substrates increases by a factor $\sim$1.5, while the cost for the polishing has to be evaluated.

4.5 TCS Cost

The costs for TCS are summarized in the following table:

Item	Number	**Tot. Cost (kE)**
Compensation plate	2	140
Heating ring	4	25
CO_2 laser	2	70
Hartmann sensor	2	60
HR face sensor	4	40
TCS TOTAL		**335**

4.6 LAS Cost

In the following table the costs for LAS (baseline solution) are summarized:

Item	**Cost (kE)**
Master laser 2 W (with 1 spare)	200
Spare diodes for 20W slave laser	100
Pre-MC	50
Electronics for pre-stab	50
Low noise detectors	50
Seismically isolated laser table	50
Motorized optical mountings, aux. optics	50
LAS TOTAL (baseline)	**550**

The ADDITIONAL costs for the optional solution (fiber laser) are summarized in this table (not included in the final cost plan):

Item	**Cost (kE)**
Fibers as amplifiers with pumping diodes	200
Fiber IMC, vac. feedth., mot. mountings, fibers coupl. opt.	100
Additional stabilization for IMC fiber	50
LAS EXTRA TOTAL	350

4.7 INJ Cost

The expected costs for INJ are summarized in the following table:

Item	**Cost (kE)**
Faraday isolator	40 (80 with 1 spare)
EOM system	20 (30 with 1 spare)
Polarizers	20
low scattering in-air optics	30
in-air mechanics	50
new Suspended Injection Bench (mechanics)	50
optics	50
electronics	50
mode matching telescope	50 (100 with 1 spare)
new resonant IMC (mirrors, mech., el.)	150
mode matching adaptive system	20
INJ TOTAL	530 (**630** with spares)

4.8 DET Cost

The costs for TCS are summarized in the following table:

Item	**Quantity**	**Tot. Cost (kE)**
Photodiodes for DC det.	16	50
Dem. boards + preamp.	30	60
LO distribution boards	15	20
OMC (Pre-MC-like)		20
Parabolic output telescope		50
Mech. for telescope and vacuum for PHD		20
Pollution mitigation in vacuum		50
DET total		**270**

4.9 DAQ Cost

The costs for DAQ are summarized in the following table:

Item	**Cost (kE)**
New racks	15
Cabling	10
Demodulation boards	40
ADC/DAC	60
SSFS digital control	20
Vacuum control system	100
New power distribution	100
CCD cameras	45
Interfaces for misc. instr. devices[3]	30
DAQ TOTAL	**420**

4.10 DAM Cost

The cost for DAT systems and disk parts will mainly be consider as maintenance of the present systems and are not included in the overall cost plan.

4.11 IME Cost

In the following table the estimated costs for the infrastructure work needed to reduce the machine noise are summarized.

Item	**Cost (kE)**
New water pipes in the central area	70
Machines and equipments for the Central Building	200
Machines and equipments for the Mode Cleaner Building	100
Machines and equipments for the Terminal Buildings (x2)	250
Infrastructure works	440
Total IME	**1060**

5 Subsystem spending profile

In this section we present a tentative spending profile for each costful subsystem. This is meant to be a preliminary exercise and will be subject to remodulation as the work of the subsystems goes on.

5.1 VAC Spending profile

All vacuum activities shall be performed before the installation of the new mirrors inside towers, to preserve the cleanliness. The expenditure will start in 2010.

5.2 SAT Spending profile

We foresee to make the expenditures for the upgrade of the IP for the long towers (except SR) in 2010 and the ones for the short towers and the construction of the SR tower in 2011. Therefore the spending profile for SAT would be:

YEAR	COST for SAT (kEuros)
2010	390
2011	715

5.3 PAY Spending profile

The expenditures for PAY are foreseen in 2011.

5.4 MIR Spending profile

The plans for the MIR expenditures are:

- **2009:** substrates purchase;
- **2010:** polishing;
- **2011:** coating.

The expenditures for metrology and cleaning investments are spread over the three years but mostly concentrated in 2009. The resulting spending profile is summarized in the following table:

YEAR	COST for MIR (kEuros)
2009	2600
2010	1410
2011	90

5.5 TCS Spending profile

The expenditures for TCS installation are foreseen in 2011.

5.6 LAS Spending profile

The LAS expenditures will be most probably done in 2011.

5.7 INJ Spending profile

A tentative spending profile is given hereby:

- **Faraday isolator:** starting from begin 2008, six months R&D are necessary. If successful, the purchase will be done in 2009.
- **EOM system:** a complete EOM should be assembled during 2009.
- **Polarizers:** thin-film Brewster polarizers are being produced in Lyon for Virgo+ (General Optics substrates). Once tested before spring 2008, new production for AdV will take place in 2008 and first half of 2009. If the high power tests on thin-film Brewster polarizers are not satisfactory, calcite-wedged polarizers have to be considered (2009).
- **Low scattering in-air optics:** 2009-2010.
- **In-air mechanics:** not before end of 2009
- **Suspended Injection Bench mechanics:** starting from 2010.
- **Suspended Injection Bench optics:** starting from 2010.
- **Suspended Injection Bench electronics:** starting from 2010.
- **Mode matching telescope:** 2010-2011.
- **New resonant IMC (mirrors, mechanics, electronics):** 2010-2011.
- **Mode matching adaptive system:** first tests at end 2008-begin 2009. Final definition in 2010.

- Possible fiber IMC: to be decided before end of 2008. To be purchased in 2009-2010.

The main part of the components should be available for installation at end of 2010.

A rough spending profile, assuming that the expenditures are done as in fig. 1, would then be:

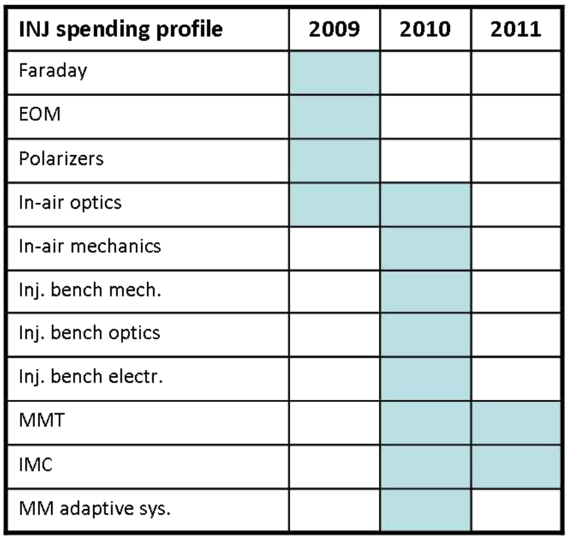

Figure 1: Expenditures plan for the INJ subsystem.

YEAR	COST for INJ (kEuros)
2009	145
2010	360
2011	125

5.8 DET Spending profile

The expenditures for DET can be done in 2011.

5.9 DAQ spending profile

A tentative spending profile for DAQ follows:

- vacuum control system: activities need to start in 2009 and will be installed in 2011-2012;
- exchange analogic loop with digital ones: activity could start in 2009-2010;
- upgrade of ADC/DAC: 2009-2010;
- power distribution: 2010-2011;
- cabling: 2011-2012;
- CCD camera: 2010-2011;
- miscellaneous: 2010-2011.

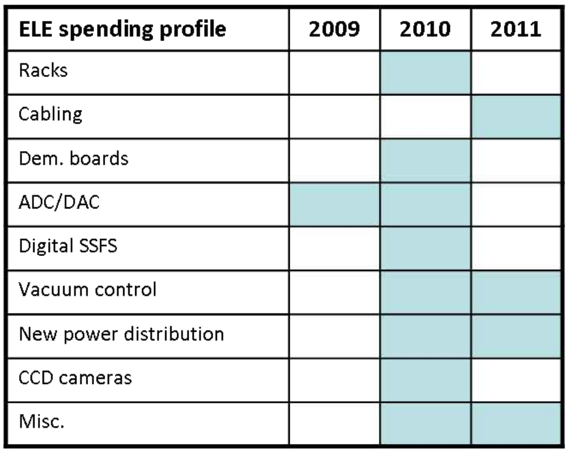

Figure 2: Expenditures plan for the ELE subsystem.

A rough spending profile, assuming that the expenditures are done as in fig. 2, would then be:

YEAR	**COST for ELE (kEuros)**
2009	30
2010	265
2011	125

5.10 IME Spending profile

If the works are to be started in 2011 part of the money should be available in 2010 for the contracts. At the moment we foresee that the IME budget could be spread over 2010-2011.

6 Advanced Virgo cost

In the following the costs for each subsystem are summarized and the total AdV cost is stated. At this early stage we consider safe to add a contingency of 30%. Taxes (20%) are also included.

Subsystem	Estimated cost (kE)
Vacuum (VAC)	960
Superattenuator (SAT)	1105
Payload (PAY)	720
Mirrors (MIR)	4100
Thermal compensation (TCS)	335
Laser (LAS)	550
Injection (INJ)	630
Detection (DET)	270
Data acquisition (DAQ)	420
Infrastructure (IME)	1060
TOTAL	**10150**
After 30% Contingency	**13195**
After 20% Taxes	**15834**

We foresee the AdV upgrade to cost about 16 MEuros. This estimates are based on 2007 prices (no escalation factor included).

7 Advanced Virgo spending profile

A tentative spending profile is proposed in the following table:

Subsystem	**2009**	**2010**	**2011**
Vacuum (VAC)		450	510
Superattenuator (SAT)		390	715
Payload (PAY)		720	
Mirrors (MIR)	2600	1410	90
Thermal compensation (TCS)			335
Laser (LAS)			550
Injection (INJ)	145	360	125
Detection (DET)			270
Data acquisition (DAQ)	30	265	125
Infrastructure (IME)		500	560
AdV	2775 **(27.3%)**	4095 **(40.4%)**	3280 **(32.3%)**
with 30% contingency	3608	5323	4264
with taxes	**4329**	**6388**	**5117**

This estimates are based on 2007 prices (no escalation factor included).