Advanced Virgo Progress Report

Report for the STAC meeting – June 11-12, 2008

The Virgo Collaboration[1]

VIR-041A-08

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1. SINCE LAST STAC MEETING

From the last STAC report:

The presented baseline is a description base of a proposal good enough to constitute a starting point for a more detailed proposal. ***The STAC considers that two milestones should be defined:***
1. a preliminary design of the AdvVirgo detector with a detailed plan for each subsystem,
2. a detailed plan for the whole system with simulations of the subsystem interplay and a detailed installation and commissioning plan.
The STAC offers to review progress towards these two milestones at its next meetings.

In the following we describe the progress towards the achievement of the milestones defined by the STAC. In this document the following points are discussed:

- AdV organization change
- Design progress
- Definition of milestones, planning started
- Definition of R&D priorities (see R&D report, VIR-042A-08)

2. ORGANIZATION

The AdV conceptual design (VIR-042A-07) and the preliminary project execution plan (PEP, VIR-043A-07) have been released in October 2007. In the PEP a four-phase evolution of the AdV project was proposed:

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

The phase 1 was over last year and AdV has been re-organized to meet the goals of phase 2. The four working groups that lead the effort of writing up the conceptual design have been replaced by a new structure, based on subsystems.

The phase 2 of the AdV project aims to preparing a preliminary design of the detector, a more accurate cost plan and PEP. A change of organization was needed to meet the new goals. The AdV subsystem breakdown had been defined in the preliminary PEP. The subsystem managers (SM) have been appointed by VSC on Apr 24/May 6 (therefore, their work has started only recently):

OSD	(Optical Simulation and Design)	A. Freise	(Birmingham Univ.)
ISC	(Interf. Sensing and Control)	E. Calloni	(INFN Naples)
LAS	(Laser)	N. Man	(OCA Nice)
INJ	(Injection system)	E. Genin	(EGO)
DET	(Detection system)	E. Tournefier	(LAPP Annecy)
MIR	(Mirrors)	L. Pinard	(LMA Lyon)
TCS	(Thermal Compensation System)	V. Fafone	(INFN Rome Tor Vergata)
SAT	(Superattenuators)	R. Passaquieti	(INFN Pisa)
PAY	(Payload)	P. Rapagnani	(INFN Rome)
DAQ	(Data Acquisition and Electronics)	R. De Rosa	(INFN Naples)
VAC	(Vacuum)	A. Pasqualetti	(EGO)
IME	(Infrastructures)	A. Paoli	(EGO)

The SM have proposed their workplan and identified the interfaces with the different subsystems. The workplans are now being reviewed to take care of overlaps and define clear responsibilities for all the tasks. The SM are responsible, within their subsystem, for:

- producing precise requirements/specifications;
- preparing the case for the selection of the open design options, including detailed planning and financial resources required;
- preparing a design and project execution plan for the subsystem they manage, to be integrated in the updated AdV documents, and work out the task breakdown.

The Head of the upgrades Department at EGO has been appointed by the EGO Council on April 21 (H. Heitmann). He is expected to help on several fronts of the project management (planning, budget, documentation, interfaces and standardization, quality), as specified in the document that defines the role profile.

The AdV web page has been updated (thanks to the EGO web team). It is now the central place for accessing all information concerning AdV (including presentations at the Collaboration meetings

and AdV biweekly meetings, official documents, technical notes, working tools etc.), and will be intensively used to keep track of the activity. A Wiki has been created with dedicated areas for each subsystem, for allowing the susbystem managers to easily store working documents in a space accessible by all, and share them among each other.

3. DESIGN

3.1 SUBSYSTEMS ACTIVITY

The SMs have started to have joint meetings in order to finalize the detector preliminary design, taking care of the impacts that each choice can have on other subsystems. A kickoff meeting of the SMs was held on May 7th to put forward the most urgent tasks to be fulfilled.
Regular AdV biweekly meetings have started on May 22nd, following the successful model of the commissioning weekly meetings.

A brief activity report for each subsystem is given in the following:

OSD The OSD work continues directly from the beginnings with the Optical Configurations working group (WG1), following the derived priorities: the work on the optical layout has been started (VIR-NOT-EGO-1390-330), a standard simulation file with a baseline configuration has been made available to the Collaboration. The finalization of the specifications for the mirror substrates, such as size, radius of curvature and wedge has begun (VIR-027A-08, VIR-037A-08 and VIR-038A-08). A trade-off has to be undertaken balancing the necessity to reduce thermal noise by having a large beam size and the constraints on the size of the coatable area on the mirrors, limited by the size of the mirror flats and the size and position of the actuators. This analysis shall be completed in autumn this year.

ISC The work on the locking strategy and the choice of the modulation frequencies has started (VIR-030A-08, VIR-032A-08). A strategy for the dual recycled interferometer locking has been outlined, which foresees the displacement of the input and SR towers. The impact on the infrastructure and vacuum is being evaluated.

LAS The tasks in progress so far for the pre-stabilized laser design, concerning the solid-state laser reference solution are:

- the investigation on the number of amplifiers needed to reach 200W starting from a master laser of 1 W or 2W;
- refining as much as possible all the specifications for pre-stabilized laser (Virgo experience plus DC detection needs);
- the preparation of a table-top experiment to check the power stabilization specification.

The fiber solution, being studied in a separate R&D, its activity is reported in the R&D topics.

INJ The design of the optical layout of AdV Injection system (INJ) is starting. The R&D activity on input optics components compliant with high power laser is well advanced (see attached R&D report). Some tests up to 90 W on magneto-optic crystal (Faraday rotator) have already been carried out and the high power test facility should be completed soon. Moreover, Virgo is starting a collaboration with the Institute of Applied Physics (Nizhny Novgorod, Russia) on the design and the realisation of a vacuum compatible 30mm clear aperture Faraday isolator able to withstand AdV power. A work that concerns in-air optical benches and which consists of defining the specifications about seismic and acoustic noise levels in order to be compliant with AdV expected sensitivity has started. Some simulation work to evaluate the effect of external benches motion on ITF noise is already used and has been validated in Virgo. This simulation can be used to define some specifications for AdV and look at the impact of different damping solutions on the ITF used.

DET The work of the DET subsystem so far has been dedicated to identifying the ITF parameters which can have a large impact on the detection system design.

- value of the modulation frequencies → OMC, photodiodes
- Schnupp asymmetry, FP finesse → mainly OMC
- beam size and power at ITF output ports (involves the stable recycling cavities issue, value of mirrors transmission/pick-off) → telescopes, diffused light issues.

This defines interfaces with ISC, OSD and INJ and work in collaboration with these subsystems is starting. Most of the listed parameters will be frozen in fall, when the optics design will be better defined.

MIR This subsystem deals with the procurement and preparation of the AdV test masses and spares (Input and End mirrors, Beam Splitter, Recycling and Signal Recycling mirror). The cavity mirrors will be thicker (200 mm or 300 mm thick), the BS will have a larger diameter (working hypothesis: 550 mm). This will induce modifications in the coating process (cleaning system, manipulation devices) and also in the metrology benches (stronger and larger sample-holders), see section on R&D. One of the main goal is to provide substrates/mirrors having a RMS flatness better than 1 nm RMS on a given spatial frequency domain. A simulation study is necessary to define precisely this domain. A tentative planning for the mirror production process has been drafted.

TCS The activity of the TCS subsystem has been mainly focused on the definition of specifications. In particular, the possibility to use compensation plates in the recycling cavity is being investigated, evaluating their interaction with the main beam and the nearby hardware and optics, and their impact on the suspension system, in collaboration with the other involved subsystems (OSD, SAT and PAY). Calculations are in progress to define the constraints on the carbon dioxide laser intensity noise, to be compliant with the design sensitivity.

SAT The isolation provided by the Virgo SA is expected to be compliant with AdV. This subsystem is focused on the enhancement of the detector robustness with respect to adverse meteorological conditions, improving the ground tilt motion compensation on the suspension top-stage, and increasing the inertial damping performance. Tiltmeters should be implemented with an angular sensitivity of about 10^{-8} rad $Hz^{-1/2}$ at 10 mHz. One prototype was delivered in April 2008 and it is presently under test in vacuum. The Virgo inverted pendulum design is being reviewed and a new prototype with stiffer legs, and three piezoelectric actuators at the base, is being put in operation. Possible modifications to the Filter 0 will be studied in simulation. New DSP and coil drivers will be implemented in Virgo+. New DAC boards with a dynamics range larger by a factor between 3 and 10 are being designed.
An important task of SAT is the management of the Signal Recycling Suspension assembly. The collection of the drawings and the check for spares of the Superattenuator parts, together with the review of the construction and the assembly procedures are to be started soon.

PAY The AdV mirror will have a thickness and hence a mass at least twice the current one, and, in one case (the beam splitter) also the diameter of the mirror will be larger than in Virgo. These constraints will require a new design of the payload geometry and structure. The introduction of a Marionette Reaction Mass (MRM) has been proposed as a possible modification aimed to overcome the limits on payload size given by the current coil pots and to simplify the suspension, tuning, and safety of the payload. It will be essential to have an accurate simulation during the design of the new payload and to plan a period of prototyping in a clean test facility in an area not

crucial for the functioning of the interferometer (e.g. 1500 W Area), before starting the payload production. The team working on the monolithic suspensions for Virgo+ has started thinking in the AdV perspective (needed size of the flats, new fiber geometry).

DAQ The activity on the DAQ subsystem is actually focused on the definition of the requirements for the data acquisition and collection, mainly in terms of dynamic range and frequency, taking into account the different characteristics of each subsystem involved in the data production and the different possible connections between the last electronic layer of each subsystem and the first layer of the DAQ. An investigation about the use, where possible, of direct optical links to reduce the signal contamination is in progress.

VAC Three tasks of VAC were already defined in the conceptual design: the realization of larger tower links , the upgrade of the SR tower to a full size UHV mirror tower, and the improvement of the clean air flow in UHV towers. Additional efforts are necessary to be compliant with AdV requirements: the first goal is to establish the tolerable residual pressure to ensure a safety factor with respect to the foreseen sensitivity and to provide suitable solutions for improving the present vacuum level (about $2\ 10^{-7}$ mbar). The proposed solutions shall take into account that the bakeout of the towers is not convenient for the interferometer operation, and cryogenics shall be probably involved. A relevant task is the displacement of towers as required by the interferometer control strategy. Finally it is considered necessary to upgrade the Vacuum Control System. All these tasks require expertise and large effort. The contribution of several laboratories is necessary.

IME The IME subsystem aims at realizing the infrastructures required by the relocation of some noise-inducing machines far away from the experimental areas to attenuate as much as possible the intensity of the anthropogenic noise. Partial solutions might be represented by the replacement of the existing machines with more silent ones, to be placed either in the existing locations or in new ones. So far the IME design activity has proceeded through:

- contacts with LIGO reference person in charge of the environmental noise analysis (Robert Schofield) to acquire useful information;
- preliminary analysis of the main actions done for LIGO and foreseen for Adv LIGO;
- draft of the infrastructure works plan aimed to individuate milestones and highlight the dates to take crucial decisions;
- individuation of an internal task force for the IME design activity mainly involved, in the preliminary phase, to the acquisition of the requirements and the priorities for the machines to be moved.

3.2 DESIGN OPTIONS

In the framework of the conceptual design some options were left open. In the following we briefly discuss the progress done with respect to such choices:

- **laser (SSL of fibre):** despite the progress done at OCA with the R&D on the use of a fibre amplifier it is now clear that such system will not be ready on the AdV timescale. **The SSL solution is then chosen. The research on fibre laser/IMC should be pursued for future upgrades of AdV**;

- **mirror mass/geometry:** the baseline solution is a mirror with the same diameter as the Virgo ones (350 mm) but twice as thick (200 mm). A heavier mirror is being considered in order to further enhance the low frequency sensitivity. **The choice will be made in autumn**;
- **actuators:** a small working group is preparing the case for the discussion. The baseline is the standard coil-magnet pair. **A choice will be made in fall;**
- TCS scheme: Advanced LIGO will make use of compensation plates. This option is being evaluated at Virgo. Concerns have been put forward about the possible drawbacks (new optical elements in the recycling cavities, problems for suspending them, …). The TCS group is studying the issue to understand whether the use of such plates is unavoidable. **A review of this topic will be made in fall**;
- use of non degenerate recycling cavities: such an option, chosen for Adv LIGO, would have a major impact on the Virgo design, requiring new suspended optics. **A review of this topic will be made in fall**;
- the use of non standard beam geometry, higher order Laguerre modes (HOLM) instead of TEM_{00}, to cope with thermal lensing and reduce the mirror thermal noise. A R&D project on this topic has been proposed (see R&D report). It is unlikely that AdV can use such modes since the beginning, but, if the right mirror geometry is chosen, HOLM could be injected later. **Keeping this option open can thus have an impact on the choice of the mirror diameter (to be made in fall) or ROC (to be made in spring 2009)**;
- the bakeout of the Virgo pipes might be necessary to stay below the AdV sensitivity with a good safety factor: it could require the installation of cryotraps to separate the tubes from the towers. The large beam size will require large vacuum links in the central area, and the diameter has to be frozen. **Those issues will be reviewed in fall.**

4. MILESTONES AND PLANNING

The AdV team has started the work on the planning for construction and installation (A working draft is available). Some important milestones have been set, more will be added in the next months as the work of the subsystems proceeds:

Oct 08: important AdV workshop to review many aspects of the design and take several crucial decisions:

- review of the **optics design**
  - review of **non degenerate recycling cavity** issue
  - decision on **cavity mirrors mass/geometry** (diameter, thickness, size of the flats)
- review of the **length sensing and control scheme**
  - review of **modulation frequencies**
  - review of the **displacement of the central towers** issue
  - decision on **actuators**
- review of the **vacuum needs** (size of the central links, residual pressure requirements)
- review of the **Thermal Compensation scheme**

Nov 08: Release of the updated AdV design and the updated Project Execution Plan and Cost Plan for AdV

Jan 09: Place the order for the mirror substrates (if funding is approved)

Spring 09: new AdV workshop to review the status of the design and take more crucial decisions:

- review of the optics and LSC design;
- review of the Higher Order Laguerre Modes option (input for the ROC);
- decide BS,PR,SR mirrors geometry;
- decide cavity mirrors Radius of Curvatures (ROC);
- decide on the needed infrastructure modifications.

Fall 09: new AdV workshop to finalize the design. The work of each subsystem will be reviewed. The point on the coating reseach will be made and the “coating recipe) will be frozen.

5. SUMMARY AND CONCLUSIONS

During the last months, also thanks to the confidence acquired with the achievements of the last phase of commissioning activities and with the approval of the ET Design Study, the motivation to realize AdV has been strenghened. It has been possible to review the organization and appoint the subsystem managers, although this step coming rather late has delayed the design progress. While Virgo+ is an important step toward Advanced Virgo and must be a success, the Virgo Collaboration will make every effort to allocate enough manpower to the AdV design, though it is likely that new resources will have to be acquired.

Given the R&D funds constraints, a list of priorities among the R&D projects has been proposed (see R&D report). We ask the STAC to review and hopefully endorse it.

About the milestones defined by the STAC at the Nov 07 meeting:

1. ***a preliminary design of the AdvVirgo detector with a detailed plan for each subsystem:***

as described in the previous pages, the subsystem manager have been appointed at the end of april/beginning of may and have started the design and planning work. A detailed plan for each subsystem will be presented in the next months.

2. ***a detailed plan for the whole system with simulations of the subsystem interplay and a detailed installation and commissioning plan.***

The subsystem managers started to work on the planning of each subsystem. The subsystem interplay and the construction and installation plan will be better defined in the next months. A preliminary discussion on the commissioning plan will also start, mostly dedicated to defining the main commissioning phases and milestones (i.e. start with or without signal recycling), while a detailed commissioning planning has to be considered a longer term milestone.