A NEW SWISS TEST-SITE FOR AVALANCHE EXPERIMENTS IN THE VALLÉE DE LA SIONNE/ VALAIS

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ABSTRACT: A new Swiss test-site for avalanche experiments has been built to study the overall dynamic behaviour of dense-flow and powder-snow avalanches and to measure avalanche impact forces along their path. An important application of the data gathered is for the verification and calibration of physical models and of computer simulation programs. For the impact studies a wall, a pylon of circular section, a girder mast and a section of the roof of a road protection gallery are placed within the avalanche track and equipped with force transducers and pressure and strain gauges. The dynamic behaviour of the avalanches is measured by Doppler- and FMCW-radars. Snow mass balances are established by photogrammetry. The avalanches are artificially released.

For many years, the Swiss Federal Institute for Snow and Avalanche Research used a test-site in the Canton Grison to study the dynamic behaviour of dense flow avalanches. The limited number of successful experiments at this site forced the institute to examine several alternatives for an avalanche test-site. It was finally decided that a site in the Canton Valais with several potential avalanche tracks with more than 1000 m of potential difference in altitude was most suitable for our purpose. After several years of planning for the test-site, the civil engineering construction work started in summer 1997, followed by the installation of sensor devices and the data acquisition, transfer and storage system. In December 1997 the test-site was ready for experiments.

KEYWORDS: avalanche deposits, avalanche mechanics, avalanche modelling, avalanche pressure, avalanche velocities, snow load on structures, impact forces.

1. INTRODUCTION

In the European Alps expanding settlements and increasing mobility due to tourism lead to a growing number of constructions in terrain threatened by avalanches. Land use planning is therefore a topic of major concern in most alpine regions of Europe. A crucial factor is the precise delineation of avalanche hazard zones, which requires methods for calculating or at least estimating the dynamics (run-out distances, impact pressures) of different types of avalanches. Many such methods have been proposed, some of which are routinely and effectively used by practitioners (Salm et al., 1990). Numerical modelling methods using FE- or FD- techniques have set new standards in the use of avalanche dynamics models (McClung et al., 1995, Bartelt et al., 1997). User-friendly GIS- and DTM-tools are additional assets to complete and facilitate avalanche hazard mapping (Gruber et al., 1998a, 1998b). Nevertheless, our present insight into the dynamics of dense-flow and powder-snow avalanches is still limited. In particular, adequate physical models to describe the flow regime of dense-flow avalanches, the snow entrainment in powder-snow avalanches (Issler, 1998) or the impact mechanisms on structures are lacking. Real progress will only be possible when field and laboratory data will be available covering all major parameters influencing avalanche dynamics. The new SLF avalanche test-site in the Vallée de la Sionne aims at providing the necessary experimental data input to further improve existing models and for the development of more realistic approaches. The test-site will be open to all research institutes interested in a cooperation (SAME, 1996). Research colleagues from Spain, France and Austria are already cooperating with different test equipment.

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2. REQUIREMENTS ON AVALANCHE DYNAMICS EXPERIMENTS

In the past decades, several avalanche dynamics field experiments have been conducted in Europe, the U.S., Russia and Japan (see e.g. Gubler 1987, Lied, 1998, Dent et al., 1998). The experiments emphasize the detailed observation of the avalanche from the release zone down to runout. A field test-site providing excellent and complete data will fundamentally increase knowledge on the principal uncertainties encountered in simulating dense-flow and powder-snow avalanches listed below. Nevertheless, laboratory tests will still be necessary to answer specific questions. New physical models and numerical simulation tools always need to be validated -or invalidated- by confronting them with well suited experiments. To this end it is important not only to compare the final result of a model (e.g. the run-out distance) with field or laboratory test data but also to separately validate the modelling of the most important processes in an avalanche and to explain discrepancies in flow depth, pressure distribution, etc. (Gruber et al. 1998a).

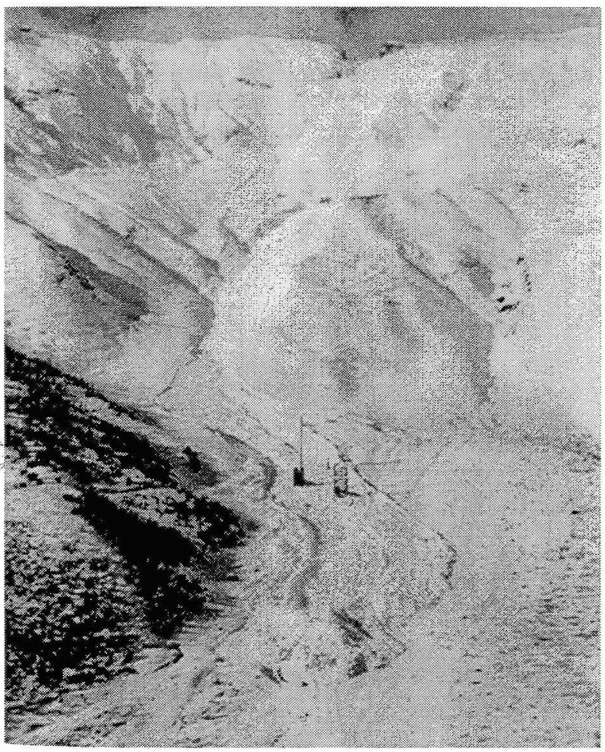

Figure 1 View on avalanche track with the location of the different obstacles

Detailed field observations will also help to improve knowledge on the various physical processes occurring in an avalanche and to assess their relative importance in view of numerical modelling. The choice of a suitable basic physical approach and theoretical framework is thus facilitated. A broad variety of parameters and uncertainties has to be taken into account when modelling dense-flow and powder-snow avalanches:

- initial conditions of the snow pack in the starting zone
- area, volume and density of released snow
- change of snow flux in the track due to snow entrainment
- topography of the track
- dependence of friction on snow properties and snow mass, terrain characteristics, vegetation
- vertical profiles of averaged flow velocities along the track and in transverse direction
- flow and deposit depths
- run-out behaviour, deceleration characteristics
- lateral spreading of the avalanche flow during run-out
- interaction of the avalanches with various types of obstacles

In addition for powder-snow avalanches:

- erodibility and suspendibility of the snow
- velocities and concentrations in the suspension layer as a function of time and space
- boundary conditions at the lower surface (velocity of the dense-flow avalanche, velocities and pressures in the saltation layer, snow entrainment)
- run-out behaviour, sedimentation rates

3. EVALUATION OF THE TEST-SITE

The following main aspects are important in the evaluation of an avalanche test-site:

- adequate return periods for small, medium and large avalanches
- test-site for dense-flow and powder-snow avalanches
- artificial release must be permitted
- channeled as well as unconstrained tracks, different slope angles
- local meteorological conditions
- secure access to observation points, protected shelter for observers and instruments
- convenient access to view points for terrestrial photogrammetry of release zones and tracks
- no danger for habited area or forests
- logistics and infrastructures nearby
- regional support and acceptance by the public
- conditions for construction work (environmental aspects, accessibility, terrain ownership, maintenance, etc.)
- good accessibility for partner institutes

After extensive evaluations the final decision was taken for Vallée de la Sionne, a site of exceptional ampleness situated north of Sion in central Valais (see Fig. 1, Fig. 2). The site is under direct influence of westerly and northwesterly winds, which increase snow deposits over the slopes. The release area is up to 30 ha with a slope angle between 32° and 45°, a track length of 2500 m, an average slope of 30° and 1200 m denivelation, starting at 2650 m.a.s.l. down to 1450 m.a.s.l. The obstacles are placed at 1650 m.a.s.l.

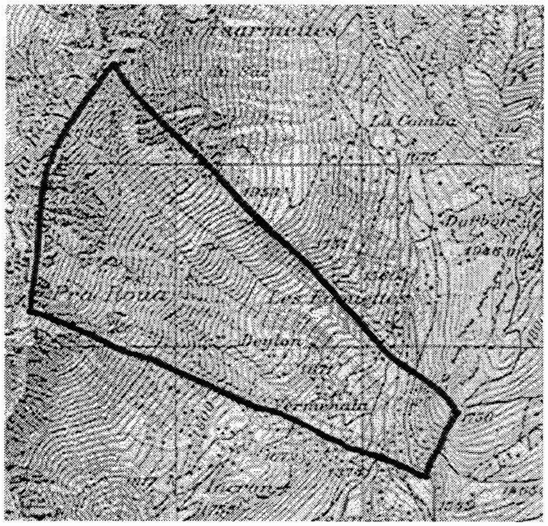

Figure 2 Situation of the SLF test-site Vallée de la Sionne, Canton Valais, Switzerland. The grid spacing is 1000 m. (Pixel map reproduced with permission of the Swiss Federal Office for Topography, Aug. 1998)

4. CIVIL ENGINEERING CONSTRUCTION WORK

For the impact studies, obstacles of different kind and shape are put into the avalanche track (Fig. 2, see also Fig. 10). The impact wall (Fig. 3) is designed as a steel construction for an impact pressure of 500 kN/m² on an area of 3.50 m x 7.00 m. The wall is equipped with 4 pressure units and 6 bi-axial load cells at the basement (sampling rate: 150 Hz).

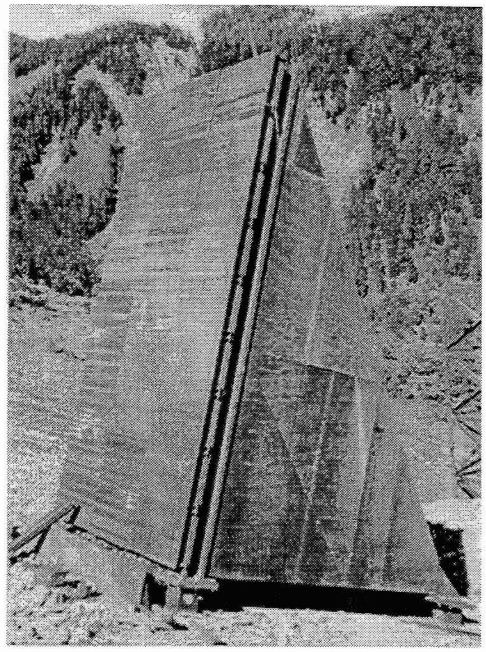

Figure 3 Impact wall with load cells and steel planks

The steel girder mast is 10 m high with a quadratic layout of 4 x 4 m (see Fig. 4 and Fig. 5). It is designed for 100 kN/m and equipped with 4 load cells and with over 60 strain gauges to evaluate the actions in the trusses (sampling rate: 150 Hz).

Figure 4 Steel girder mast

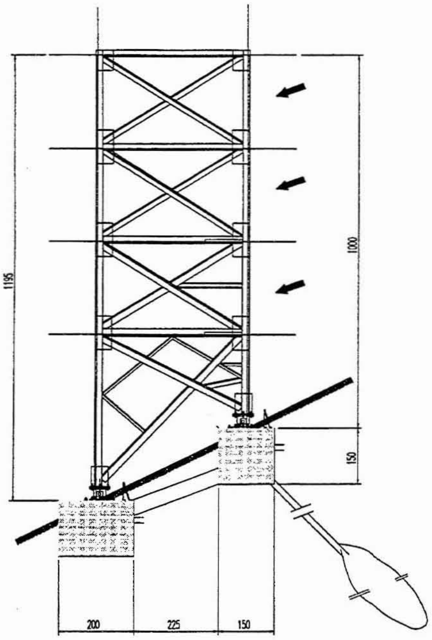

Figure 5 Cross section of the steel girder mast

To be able to measure local impact forces which are influenced the least possible by any shape factor of a supporting structure, a specific steel construction (narrow wedge, Fig. 6) has been designed and equipped with 9 pressure cell channels (15 kHz sampling rate). This narrow wedge is 5 m high (Fig. 7).

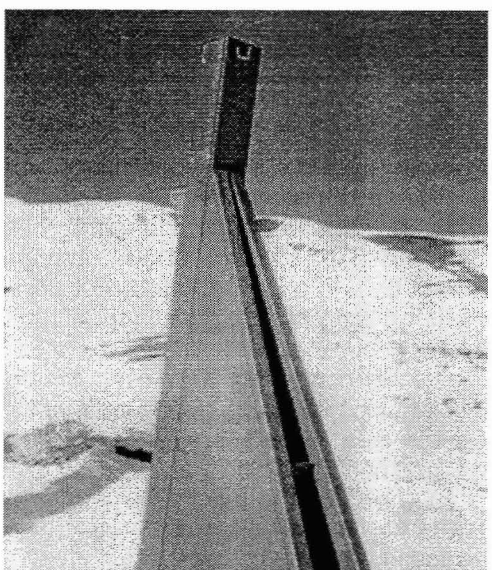

Figure 6 Narrow wedge steel construction

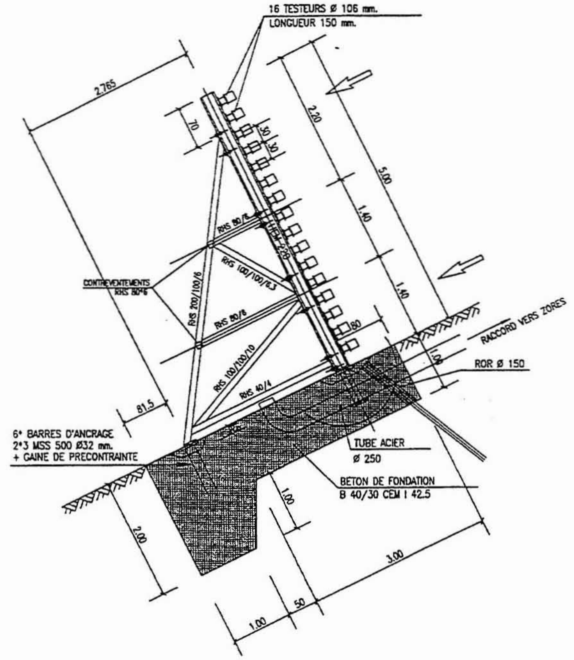

Figure 7 Cross section of wedge

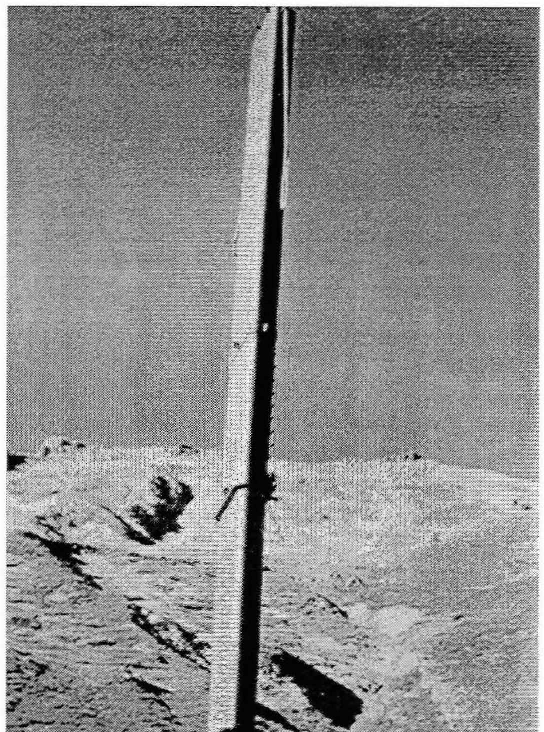

Figure 8 Steel pylon with twin tubes

To determine impact forces on circular sections and to be able to measure the pressure due to powder-snow avalanches at this site, a tubular pylon has been erected with 20 m in height, also equipped with 4 pressure cells (15 kHz sampling rate) and 16 strain gauges (150 Hz sampling rate) to detect the acting forces (Fig. 8).

A segment of a road gallery roof is additionally placed on ground and also equipped with 4 bi-axial load cells, measuring at a sampling rate of 150 Hz.

A shelter construction just opposite to the avalanche track at 1500 m.a.s.l. protects the staff members , observers and the Doppler radar units and serves also as data storage center. It is designed for an overall impact pressure of 15 kN/m² and a point load of 1200 kN. The dimensions are 5 x 6 x 9 m (Fig. 9). The transfer of the test team to the shelter is provided by helicopter with a landing plattform on the roof to secure fast entrance to the shelter in case of increased avalanche danger.

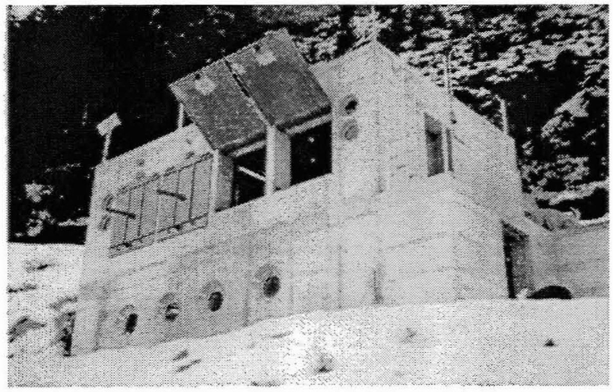

Figure 9 Shelter construction with observation portholes at ground level and the openings for the Doppler radars on the first level. The openings can fast and easily be closed to protect the radar equipment in case apowder-snow avalanche would hit the shelter

5. AVALANCHE VELOCITY MEASUREMENTS

For local velocity profile measurements of the avalanches, three pairs of FMCW radar units are buried in the track, the first at 2300 m.a.s.l., the second at 1900 m.a.s.l. and the third one just above the obstacles. The FMCW radars also serve to determine erosion rates. The sampling rate is 33 kHz.

Doppler radar technique is used to measure he front velocity of dense-flow and powder-snow avalanches. Five units are placed in the upper floor of the shelter each targeting different segments of the whole track. The sampling rate is 15 kHz.

6. MASS BALANCE MEASUREMENTS

In order to establish the mass balance of an avalanche, the snow distributions before and after the avalanche release have to be measured. During a pre-evaluation, high precision distance measurement applications based on laser technology failed due to the long distance (>2500m) between instrument location and release zone, and the small angle of inclination of the laser beam (< 20°). Therefore the method of photogrammetry has been chosen. To ensure the orientation of the photographs, many reference points have been clearly marked out at locations in the terrain which are likely to remain visible even after important snowfalls. Oblique photographs at a scale of 1:5000 are taken from a helicopter using a medium format camera (Linhof, 9x12cm). This configuration provides an accuracy of approximately ±25cm even under conditions of moderate contrast. The reason for taking the photographs from a helicopter is, that in comparison to a plane, a helicopter is much more flexible when it comes to choosing the optimum moment with respect to contrast for taking the pictures.

7. ACQUISITION; TRANSFER AND STORAGE OF DATA

The different sensors, strain gauges and pressure and load cells of the different construction elements are linked to decentralized data acquisition computers for which local, underground shelters have been built (Fig. 10, Fig. 11). An immediate transfer of all data to a central unit is not possible due to the large amount of samples (up to 1 million samples per second or 120 million samples per event). The local computers are linked through a central back-bone, containing a fibre optic network, to the central data storage system in the shelter construction. The fibre optic network has a total length of 2300 m, starts at the shelter and goes up to point A in Fig. 10. After an event all data from the decentralized storage units are gathered and then stored in the central unit in the shelter (LAN 242 MBytes per event).

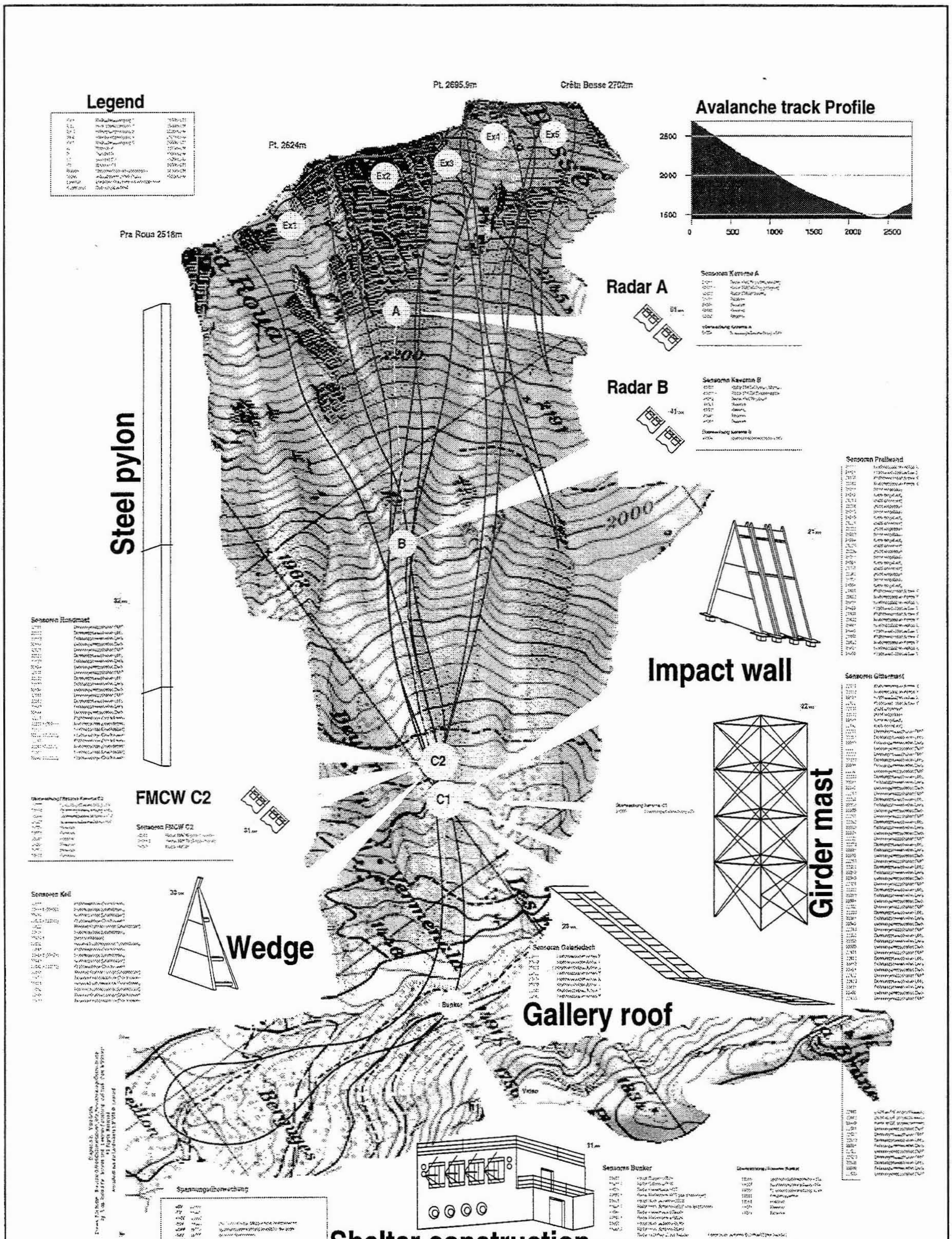

Figure 10 Overview of the test-site, the location of the different obstacles and radar units(A, B, C2) with the corresponding sensor units, pressure and load cells and strain gauges, the positions of artificial avalanche release (Ex1 to Ex5) and corresponding avalanche tracks (black lines). (Pixel map reproduced with permission of the Swiss Federal Office of Topography, Aug. 1998)

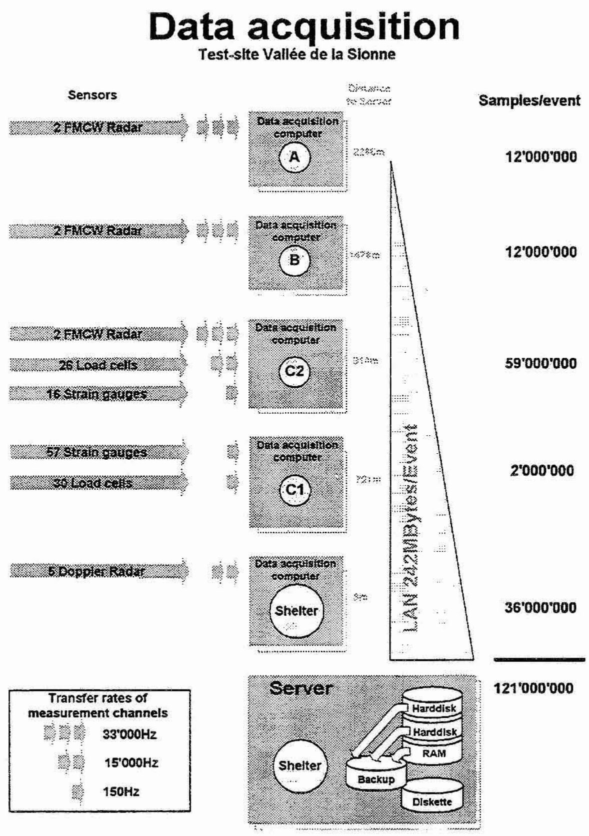

Figure 11 Schematic sketch of data acquisition

8. AVALANCHE RELEASE

When heavy snow falls are expected a special alert plan is used to ensure that the SLF test team and the partners from other European countries are in due time on the test-site. A new snowcover simulation programme developed for avalanche warning (Lehning et al., 1998) provides additional information on the snowpack in the release zone. The corresponding snow and weather information is gathered by an automatic station nearby the avalanche track. Artifical avalanche release is provoked by explosive charges thrown from a helicopter or by mortar. In case of naturally released avalanches a special trigger system using seismic sensors positioned at point A, B, C2 (see Fig. 10) will initiate the whole data acquisition system except the Doppler radars so that also unexpected events can be taken.

9. CONCLUSIONS

The new SLF avalanche dynamics test-site in the Vallée de la Sionne will provide extensive data on different parameters of dense-flow and powder-snow avalanches including velocity measurements along the avalanche track, evaluation of impact actions on different obstacles, photogrammetric evaluation of released and deposited snow volumes, continuous automatic snow and weather observations and additional visual observations. All this information shall lead to a fundamentally improved understanding and modelling of avalanches and specifically serve for validation purposes of newly developed computer software.

10. ACKNOWLEDGEMENTS

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