A Strategic Plan for Mathematical Sciences at the University of Colorado

or staying within the mathematical legacy of Stanislav Ulam

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Probably the most famous mathematician at the University of Colorado, Stanislav Ulam (13 April 1909 – 13 May 1984), made major contributions to topology, functional analysis, number theory, set theory, and in particular to mathematical physics and mathematical biology. These are also major areas where the Department of Mathematics presently still has its strengths or which should be revived and where the Department should become strong again.

Vision

The Department of Mathematics should envision

- to broaden and enhance mathematical research activities on campus and their impact,
- to increase its visibility and foster synergies,
- to improve the PhD program,
- to improve undergraduate education.

The strategic plan to put this vision into reality is

1. to unite research in and teaching of Mathematics in one Department of Mathematics and to create a Department of Statistics and Computational Sciences,
2. to establish research groups in *Mathematical Physics* and *Mathematical Visualization*,
3. to extend and solidify the postdoc program,
4. to improve undergraduate education by diversification and better preparation for graduate school and careers in secondary education, government, industry and business,
5. to hire the faculty and to create the infrastructure for the realization of the vision.

1. Unification of Mathematics and creation of a Statistics and Computational Sciences department

The present situation of a complete separation into a Mathematics Department, an Applied Mathematics Department and various statistics groups on campus is undesirable and inefficient, both from a scientific as well as an economic standpoint.

The proposal of this strategic plan is to create one united Department of Mathematics within the College of Arts and Sciences and a Department of Statistics and Computational Sciences which could be located either within the College of Arts and Sciences or within the Engineering College. The statistics and computationally oriented faculty of the present Department of Applied Mathematics should be the founding members of the Statistics Department to be created, the more mathematically oriented faculty of APPM should become faculty members of the re-united Department of Mathematics. Double memberships in both departments, for example of faculty working in probability theory or in non-linear PDE's, should be encouraged. There are several reasons for the proposed reorganization of mathematical, statistical and computational sciences on campus:

(a) Mathematics on one hand and statistics, scientific computing on the other have quite different methods and customs of research and research funding.
(b) The present split in two mathematics departments has created duplications of courses and an unhealthy struggle to attract students for the same courses offered in two different departments.
(c) Having two mathematics departments has created unnecessary additional administrative structures.

(d) The split of mathematics in pure and applied mathematics was in part a creation after WWII which in the majority of mathematical institutes has been overcome now because it was artificial and politically motivated.
(e) A (re-)unification of the mathematics departments will allow mathematics faculty at CU Boulder to follow and contribute to the scientific trend in which highly theoretical methods in mathematics find increasingly unexpected applications, for example, abstract methods from algebraic topology in biochemistry.

2. Research groups in *Mathematical Physics* and *Mathematical Visualization*

Starting with Ulam and later Richtmyer in the Mathematics Department, Barut in the Physics Department and following hires in mathematics, CU Boulder had built up quite a strong group working in mathematical physics and related areas. It is the plan to revive mathematical physics within the Department of Mathematics and actually even expand it to a group (including degree) *Mathematical Physics* with connections to physics, chemistry, and biology. Besides the strong and renowned tradition of mathematical physics at CU Boulder the striking new (and many old) applications of abstract methods from modern mathematical areas like topology, algebraic geometry, and functional analysis to problems within the sciences promise this vision to be fascinating, intellectually stimulating and successful. Moreover, the Department of Mathematics being part of the research developments in these interdsiciplinary areas probably will open new extramural support. Some problems which are exemplary are the attempts to understand protein geometry and topology, to find the mathematical structures behind elementary particle theory, or to describe the spectral theory of Schrödinger operators encoding the quantum mechanics of molecules. Potential connections with certain groups in other departments will not only strengthen these endeavors for the Department of Mathematics but also might lead to synergistic effects between the science departments and the Mathematics Department.

In the long run it is planned to create a BA and/or Masters degree in *Mathematical Physics*. Particular hires in the field of mathematics of the sciences could be in Schrödinger operator theory (connection with quantum mechanics and physical chemistry), in applied topology (with emphasis on applications in molecular biology and/or chemistry), and in Poisson geometry and hamiltonian systems.

Last but not least, a revival of mathematics of the sciences in the new Department of Mathematics can build upon existing professorships, in particular those in geometry, topology, functional analysis, algebraic geometry and dynamical systems (in APPM) which already have some overlap with the sciences.

The Department of Mathematics should plan to strengthen its visibility in several theoretical disciplines as well. The recent hires in algebraic geometry, foundations, probability, topology and geometry contributed to that, in particular since some of the newly hired junior faculty have already made considerable contributions to their respective fields and achieved significant extramural support. It is intended that the Department will further increase its visibility by hosting more workshops and conferences.

A vision for further expansion is in the direction of mathematical visualization. The Department of Mathematics has already several groups, in particular the algebra, number theory and geometry groups, which work with computer algebra systems such as gap, sage, maple or mathematica. In particular with a view towards the fact that many graduates of the Department of Mathematics find employment in industry, the Department of Mathematics should envision building up a mathematical visualization group. This group will have connections with the existing algebra, number theory, geometry, topology, dynamical systems and non-linear PDE's groups (the

last two in APPM) and potentially new connections to a mathematics in the sciences group, where mathematical visualization plays an important role as well.

3. Postdoc program

Postdocs play a crucial role for the research activities of any mathematics department. In addition, postdocs in mathematics usually have teaching experience, and therefore contribute to strengthening the old and well-proven Humboldtian ideal of unity of research and teaching. It is suggested to solidify and extend the postdoc program in the Department of Mathematics by increasing the number of postdocs to roughly a third of all TTT faculty in the Department of Mathematics. Moreover, the duration of stay of a postdoc at the department should increase from 2 years to 2+1 or 1+2 years (with an evaluation in between).

4. Diversification and regulation of PhD program

The Department of Mathematics should extend the spectrum of topics of graduate courses in mathematics to address the new developments in theoretical mathematics and its applications. Moreover, the Department of Mathematics should revise its written regulations for granting a doctoral degree and supplement these with a precise explanation of what is expected in a mathematics dissertation and procedures for the formation of exam committees.

5. Improvement of undergraduate education

Presently, over 30 semesterwise hired lecturers and over 30 graduate students teach the majority of lower division undergraduate classes in mathematics to test the *small class* philosophy favored by a few faculty members specializing in mathematics education. By far most students of mathematics have not seen a mathematics professor in class before they enter their junior or senior year. This model of college mathematics education is an experiment which neither is sustainable nor does it provide the necessary preparation in mathematics for graduate school and careers in industry, business, secondary education and government. Moreover, because that model inherently requires that lecturers of these classes need to be taught how to teach, teaching of mathematics within the *small class* model is standardized, often at the lowest level possible. This neglects the extremely different levels our incoming students have in mathematics and the profound mathematical knowledge a career in the sciences or in engineering demands.

It is proposed to immediately start to teach mathematics in larger classes again, and to require that from the level of calculus on the corresponding lectures are only taught by rostered instructors, postdocs and professors in mathematics. It is suggested to diversify lower division undergraduate education in mathematics by introducing two or three major lines of courses such as for example *Proof oriented Calculus for Mathematics and Physics majors*, *Computationally oriented Calculus for Science and Engineering majors* and *Calculus for Business and the Social Sciences*.

The overall impetus for undergraduate eduction in mathematics should be to teach larger classes again with three hours lectures per week given by faculty and have a solid tutorial program on all levels. The tutorials should be given by graduate students which would help them to acquire the necessary teaching qualifications for a career in academia. Last but not least the offered course spectrum in mathematics needs to be diversified to reflect both the present developments in mathematics and the demands of the industries or institutions where our mathematics students later will work.

The new Department of Mathematics and the new Department of Statistics and Computational Sciences should have a joint undergraduate curriculum committee which would be charged with developing a core curriculum for the mathematical sciences on campus.

6. Hiring personnel and creation of infrastructure

The student credit hours the Department of Mathematics creates are enormous and the highest on campus. The number of faculty within the Department of Mathematics is by far not sufficient to fulfill its teaching obligations. It is not comparable with our peer institutions like CU Berkeley, UT Austin, University of Wisconsin, Ohio State, Texas A&M, etc. which all have more than 70 mathematics faculty, one even more than 100 TTT faculty. In comparison, the two mathematics departments at CU Boulder together still have less than 50 professors. It is therefore suggested to increase the number of TTT faculty in the Department of Mathematics to one which is comparable to CU's peer institutions and which reflects the importance of mathematical knowledge in the sciences, engineering and industry.

Increasing numbers of freshmen classes in mathematics and the sciences led to an urgent need of appropriate classrooms at CU Boulder. For example the number of classrooms in the ECCR building and their equipment in particular with blackboards is insufficient. It is therefore proposed that CU Boulder initiates the construction of a new classroom building for mathematics and the sciences.

To address the growing number of people working in mathematics on campus it is suggested to build a fourth floor on top of the MATH building; it appears that that building already has been designed so that such an extension is possible.