# Interdisciplinary research at Bell Labs

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Lucent Technologies
Bell Labs Innovations

# Outline

## Three projects

| | |
|---|---|
| 1994-1998 | WISE: wireless system engineering |
| 1998-2003 | Ocelot: cellular system optimization |
| 2001-present | Frog: optical network simulation |

## Value

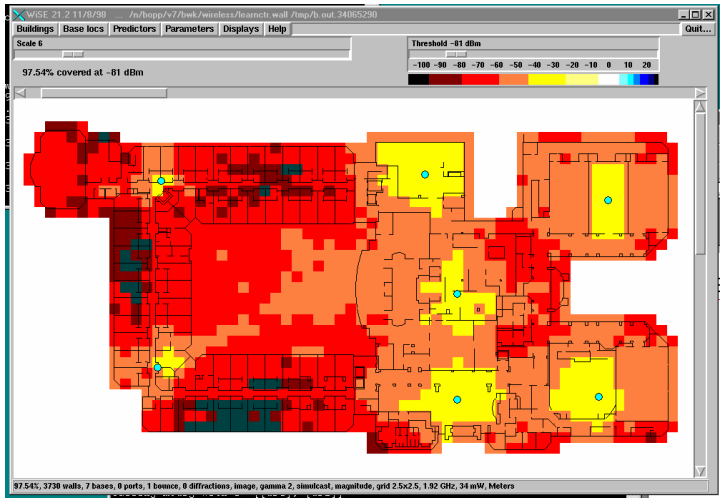
## Success indicators

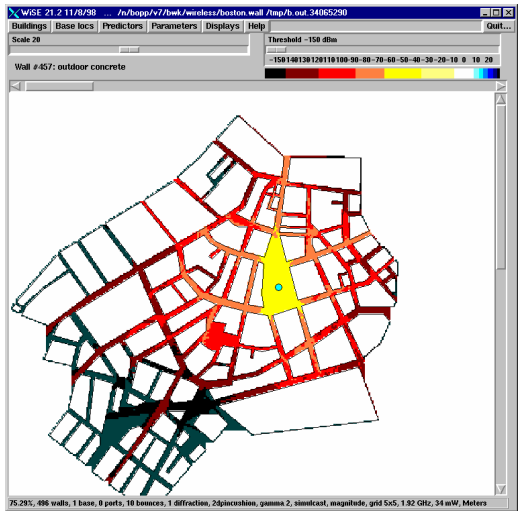
## Challenges

Caveats:

- industrial research
- `modelling + algorithms + database + gui'
- computer science viewpoint

# WISE: wireless system engineering




Initial problem:

in-building wireless system design

Eventual functionality:

predict propagation in complex environments

optimize antenna locations

Methods:

CS: ray-tracing, computational geometry, derivative-free optimization, GUI, software engineering

Radio: propagation modeling

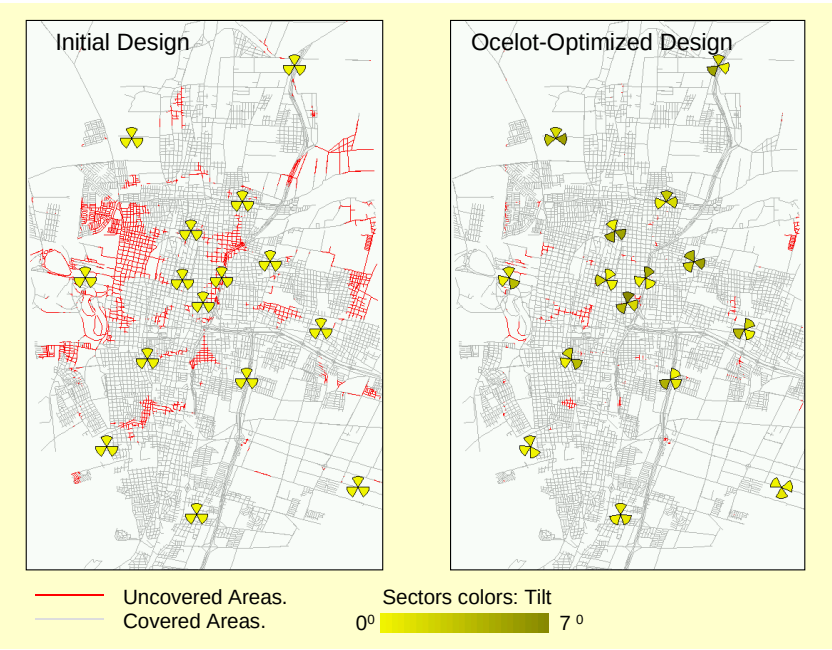
Innovations:

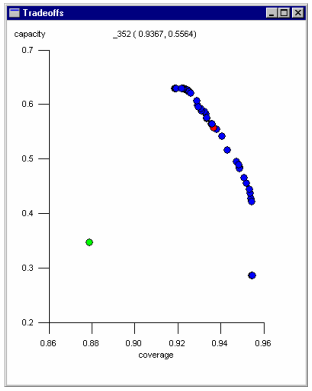
Algorithms, modeling, measurements

Steven Fortune, Margaret Wright, Brian Kernighan, Reinaldo Valenzuela, Dmitry Chizhik, Jon Ling, Vinco Erceg, ….

# Ocelot: Cellular optimization tool

**Coverage Improvement With Ocelot**




Initial problem:

reduce drive tests for installation of cellular systems

Eventual functionality:

predict coverage-capacity tradeoff
optimize power, antenna direction, pilot

Expertise:

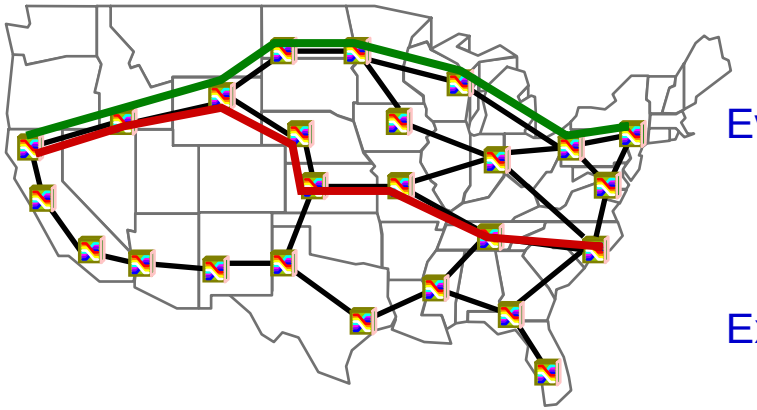
nonlinear optimization, stochastic modeling, geometric algorithms, software engineering

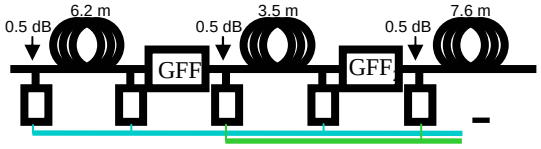
Innovations:

comprehensive, differentiable, analytic models of cellular systems

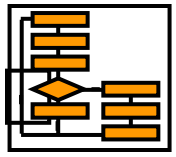
Ken Clarkson, John Hobby, John Graybeal, Howard Trickey, Paul Polakos, Alvaro Diaz, Chandra Chekuri, Lisa Zhang, David Abrusch-Magder, Larry Drabeck, Georg Hampel, Jay Srinivansan, …

# FROG: physical-level WDM optics simulation






$$\frac{\partial \rho^+(z,t,\nu)}{\partial z} + \frac{1}{v_g(\nu)}\frac{\partial \rho^+(z,t,\nu)}{\partial t} = -\alpha(\nu)\rho^+(z,t,\nu) + \gamma(\nu)\rho^-(z,t,\nu)$$
$$+ \rho^+(z,t,\nu)\int_{\zeta>\nu} g(\nu,\zeta)\left(\frac{\rho^+(z,t,\zeta)}{K^{++}(\nu,\zeta)} + \frac{\rho^-(z,t,\zeta)}{K^{+-}(\nu,\zeta)}\right)d\zeta$$
$$- \rho^+(z,t,\nu)\int_{\zeta<\nu} \frac{\nu}{\zeta} g(\zeta,\nu)\left(\frac{\rho^+(z,t,\zeta)}{K^{++}(\nu,\zeta)} + \frac{\rho^-(z,t,\zeta)}{K^{+-}(\nu,\zeta)}\right)d\zeta$$
$$+ 2h\nu\int_{\zeta>\nu} (1 + n_T(\nu,\zeta))\, g(\nu,\zeta)(\rho^+(z,t,\zeta) + \rho^-(z,t,\zeta))\, d\zeta$$



**Initial problem:**

Design optical amplifier control algorithms

**Eventual functionality:**

both steady-state and dynamic simulation of amplifier power levels

**Expertise:**

CS: PDEs, discretization, software

Optical: Raman, Rayleigh back-scattering, fiber propagation, …

**Innovations:**

Multiscale (μs-ks, m-Mm), huge state space

Simulation of both physics and control alg

Tin Ho, Todd Salomon, Wonsuck Lee, Bruce Hillyer, Chris White, Lawrence Cowsar, Roland Freund, Dan Kilper, …

# Value

## Wise

Technical:  state-of-the-art in 1995, still seems to be state-of-the-art

Simulations, e.g. MIMO

Business: market evolved unexpectedly;  blueprint acquisition

## Ocelot

~90 RF engineers, ~10 support staff;  middle swath of China

CTIA roll-out in 2001: established Lucent credibility in CDMA

## FROG

risk mitigation: laboratory simulation of $100M networks

Lucent credibility in ultra-long-haul optical networks

# Computer Science Essential

**Wise**

at least x1000 improvement in algorithms

geometric algorithm implementation

effective derivative-free optimization

**Ocelot**

forget simulated annealing:

project driven by need for continuous, differentiable objective function

probability, queuing theory, statistics, geometric algorithms, …

**FROG**

choice of PDE solver

adaptive grids, multiscale event simulation

software: architecture, databases, GUI, feature management

# Success indicators

## Clear problem statement

- mini ``Grand Challenge''
- team: goal-oriented, not discipline oriented

## Address cultural pitfalls

- learn each other's language
- expectations: contributions, paper authorship, …
- respect: CS is much more than coding

## Project organization

- Project 'angel'

## Start small; get to demo quickly

- communicate; build support; discover deeper models and issues

# Evaluation and rewards

Computer science, even sophisticated computer science, is essential, but the results (in these cases) are primarily not computer science

- Dozens of publications, most not in CS journals
- perception: individual PI reputation in CS degraded, not enhanced

Who evaluates? Who gets the credit? How is work rewarded?

Bell Labs:

- long tradition of evaluating and respecting interdisciplinary work
- plenty of reward mechanisms
  - (4 DMTS, 2 BL Fellows, 3 DH, 1 VP; internal awards; raises, bonuses, etc.)

# Promoting university interdisciplinary work

## Culture change

- medieval guild model
- tenure promotes specialization
  - interdisciplinary work requires breadth

## Motivational arguments

- broader impact
- exciting
- new, well-motivated, real problems within discipline
- funding agencies like new directions

## Actions

- curriculum: ``algorithms in the real world''
- outlets in prestigious journals
- CS chairs: pre-tenure: discourage; post-tenure: encourage
- Deans: break down barriers, interdisciplinary centers, …