Announcements
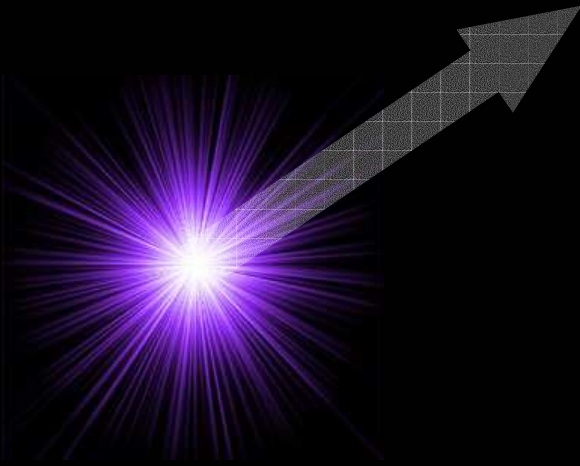
- **Programming Assignment 3 is out**
  - Due in two weeks
  - On today's topic: Particle systems
- **Midterm on Thursday October 23.**
- **Written assignment 1 is graded**

Introduction to Simulation: Particle Systems

Introduction
Differential Equation Basics
Particle Systems

COMPUTER GRAPHICS

15-462

Doug James   10/08/03

References

- W. T. Reeves, Particle Systems - a Technique for Modeling a Class of Fuzzy Objects, ACM Transactions on Graphics, 2(2), pp. 91-108, 1983.
    - http://portal.acm.org/citation.cfm?id=357320&dl=ACM&coll=portal&CFID=12858257&CFTOKEN=79986367

- Karl Sims, Particle animation and rendering using data parallel computation, ACM SIGGRAPH Computer Graphics, v.24 n.4, p.405-413, Aug. 1990
    - http://portal.acm.org/citation.cfm?id=97923&dl=ACM&coll=portal&CFID=12858257&CFTOKEN=79986367

- A. Witkin, D. Baraff, M. Kass: Physically-Based Modeling, *SIGGRAPH tutorial course notes.* 2001
    - http://www.pixar.com/companyinfo/research/pbm2001/

- Partial slide credit: Thomas Funkhouser

Kinematics and Dynamics

- Kinematics
  - Considers only motion
  - Determined by positions, velocities, accelerations
- Dynamics
  - Considers underlying forces
  - Compute motion from initial conditions and physics

- Today: *Passive Dynamics*:
  - No muscles or motors
  - Examples:
    - » Smoke
    - » Water
    - » Cloth
    - » Fire
    - » Fireworks
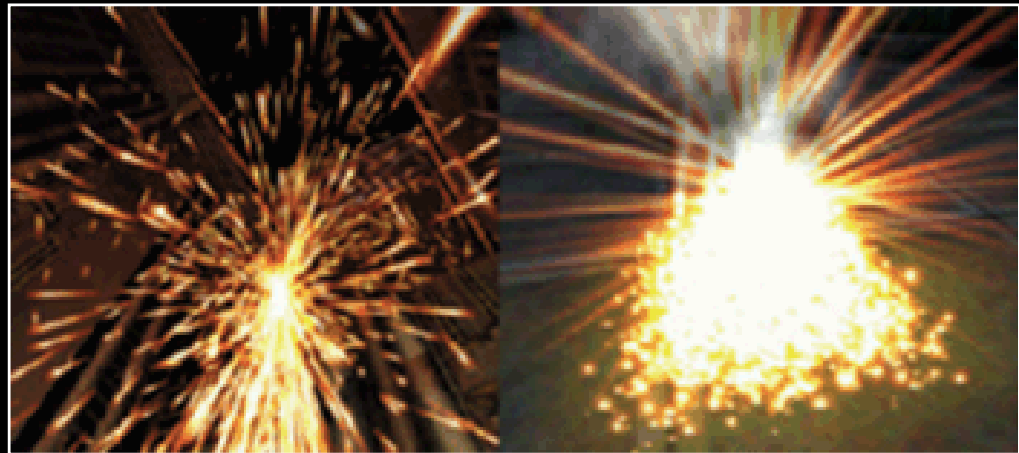
**Karl Sims,
Particle Dreams**

Particle Systems

Clouds
Smoke
Fire
Waterfalls
Fireworks

Reeves '83, the Wrath of Khan
Batman Returns, using Reynold's flocking algorithms
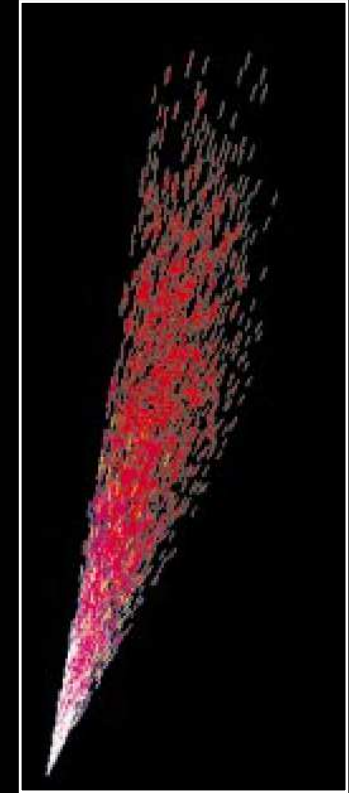
Particle Systems

- For each frame:
  - Create new particles and assign attributes
  - Delete any expired particles
 - Update particles based on attributes and physics
  - Render particles

Creating/Deleting Particles

- Where to create particles?
  - Around some center
  - Along some path
  - Surface of shape
  - Where particle density is low
- When to delete particles?
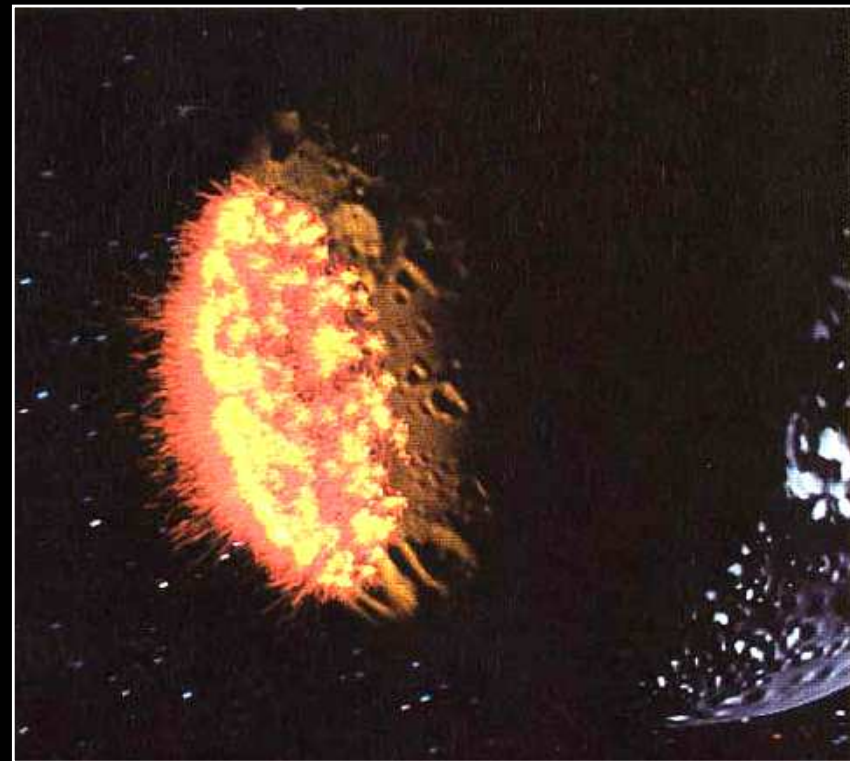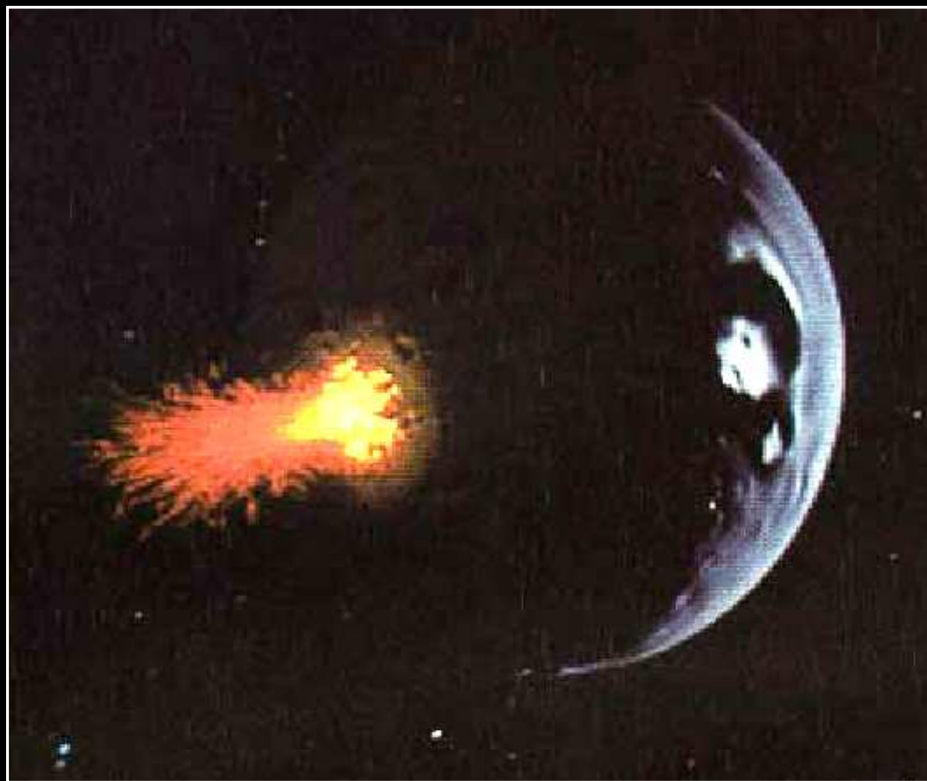 - Where particle density is high
  - Life span
  - Random

This is where user controls animation

Example: Wrath of Khan

Fig. 2. Distribution of particle systems on the planet's surface.

Example: Wrath of Khan

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Reeves
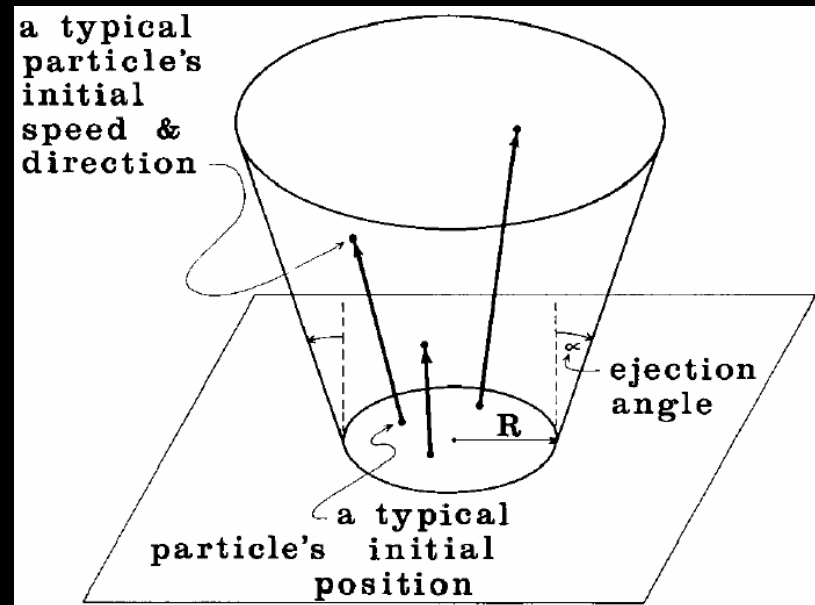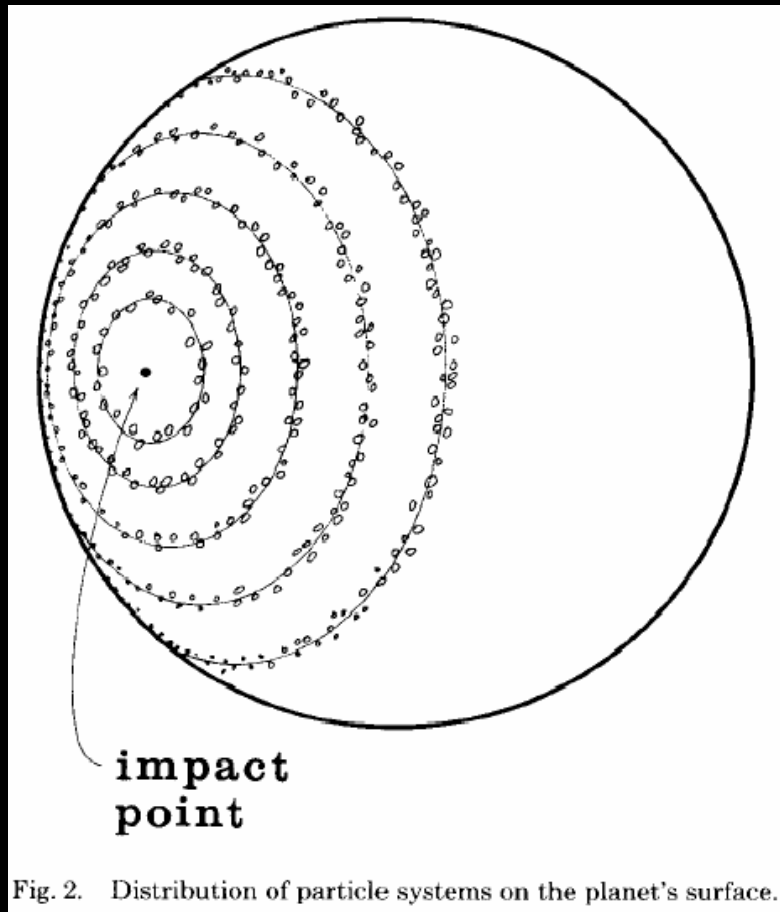
Example: Wrath of Khan
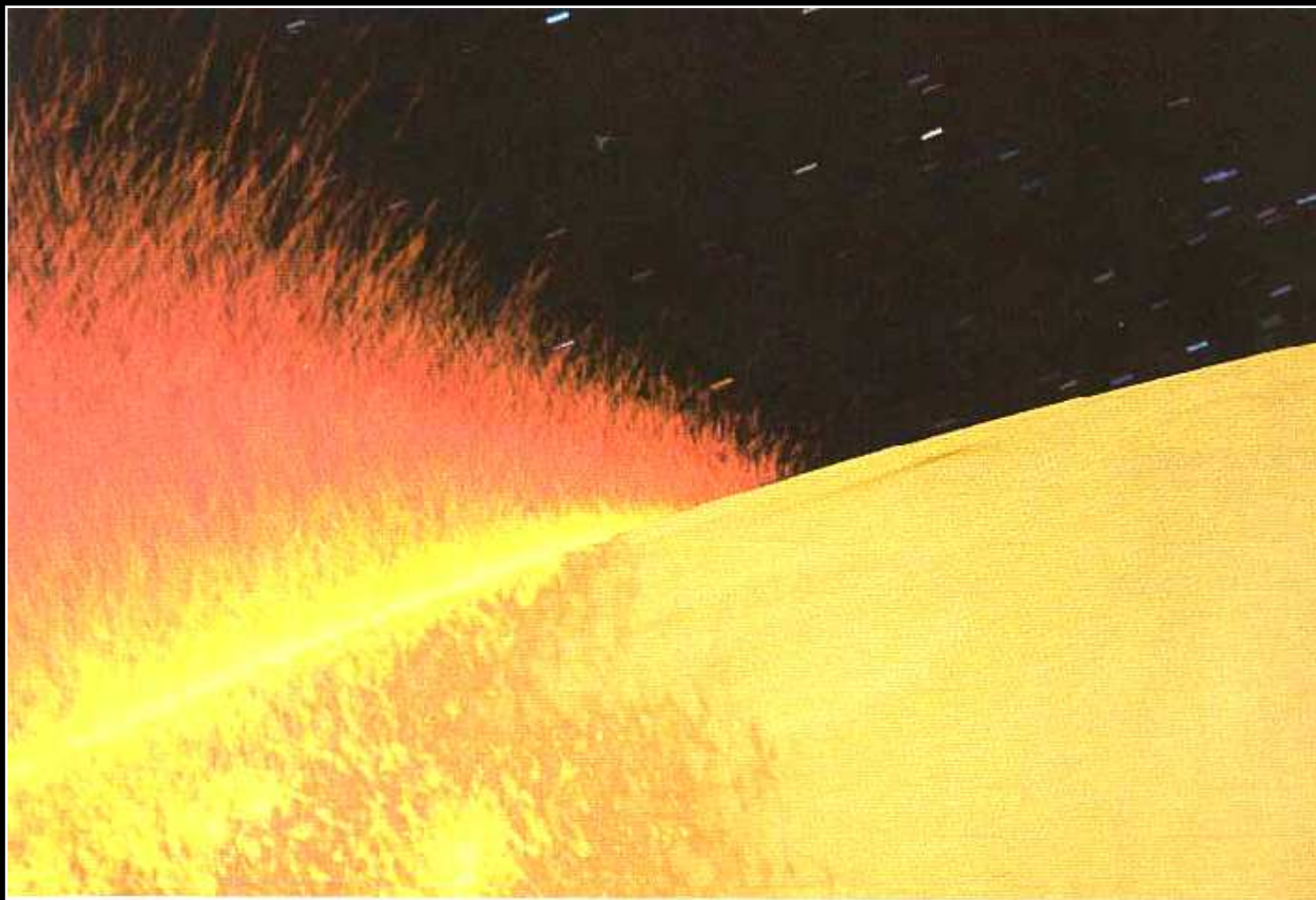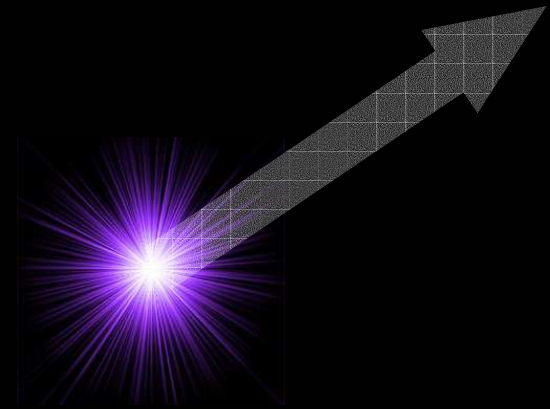

Fig. 7. Wall of fire about to engulf camera.

Particle System Attributes

- Creation—number, initial condiions
    - position/velocity
        - randomness
        - surface of emitter shape
        - vertex of polygonal object
    - size
    - color
    - transparency
    - shape
    - lifetime
- Deletion
- Update of position/velocity
    - translation
    - vortex
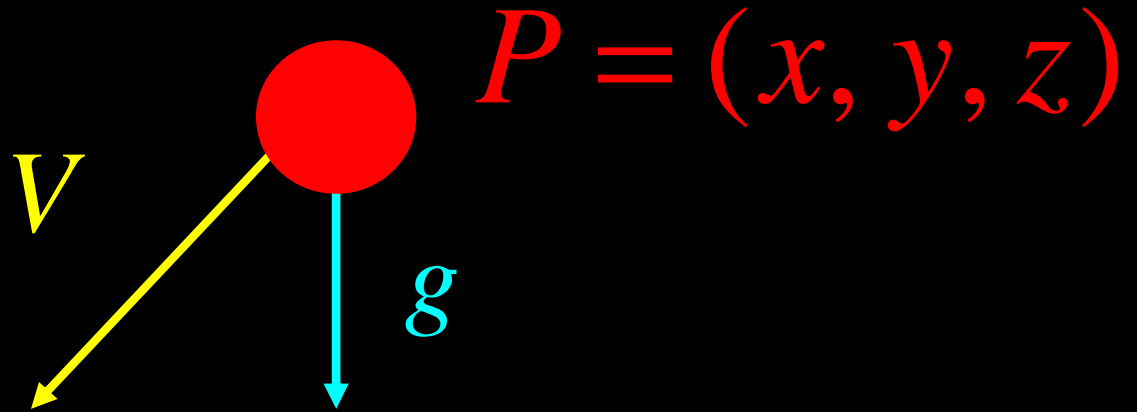- Rendering style – motion blur, compositing

What control handles
do we want/need?

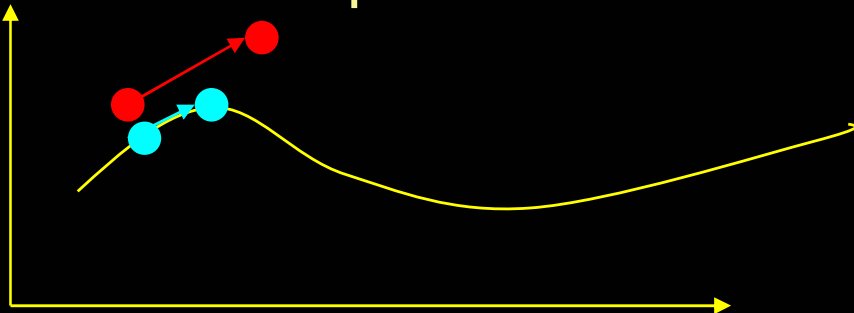# Equations of Motion: Gravity Only!

$$A = g$$

$$V' = V + A\Delta t$$

$$P' = P + \frac{V + V'}{2}\Delta t$$

$$P = (x, y, z)$$

V

g

Integration: accuracy improves as step size decreases but never a perfect match
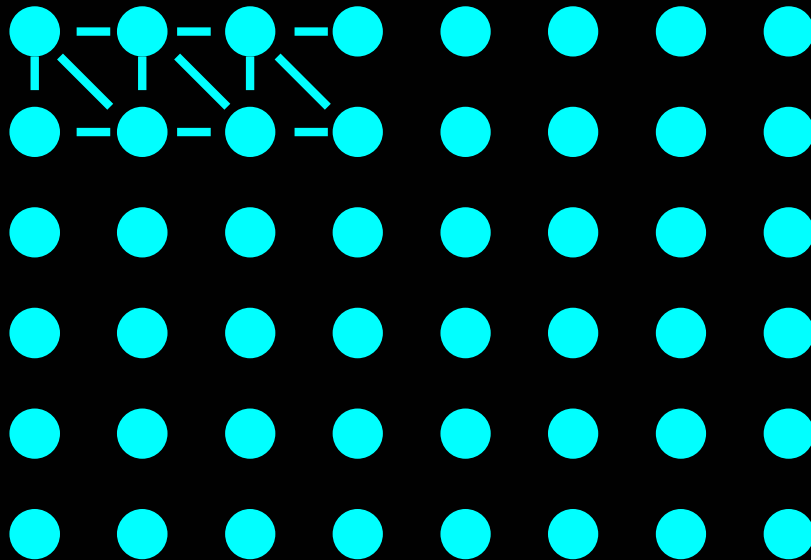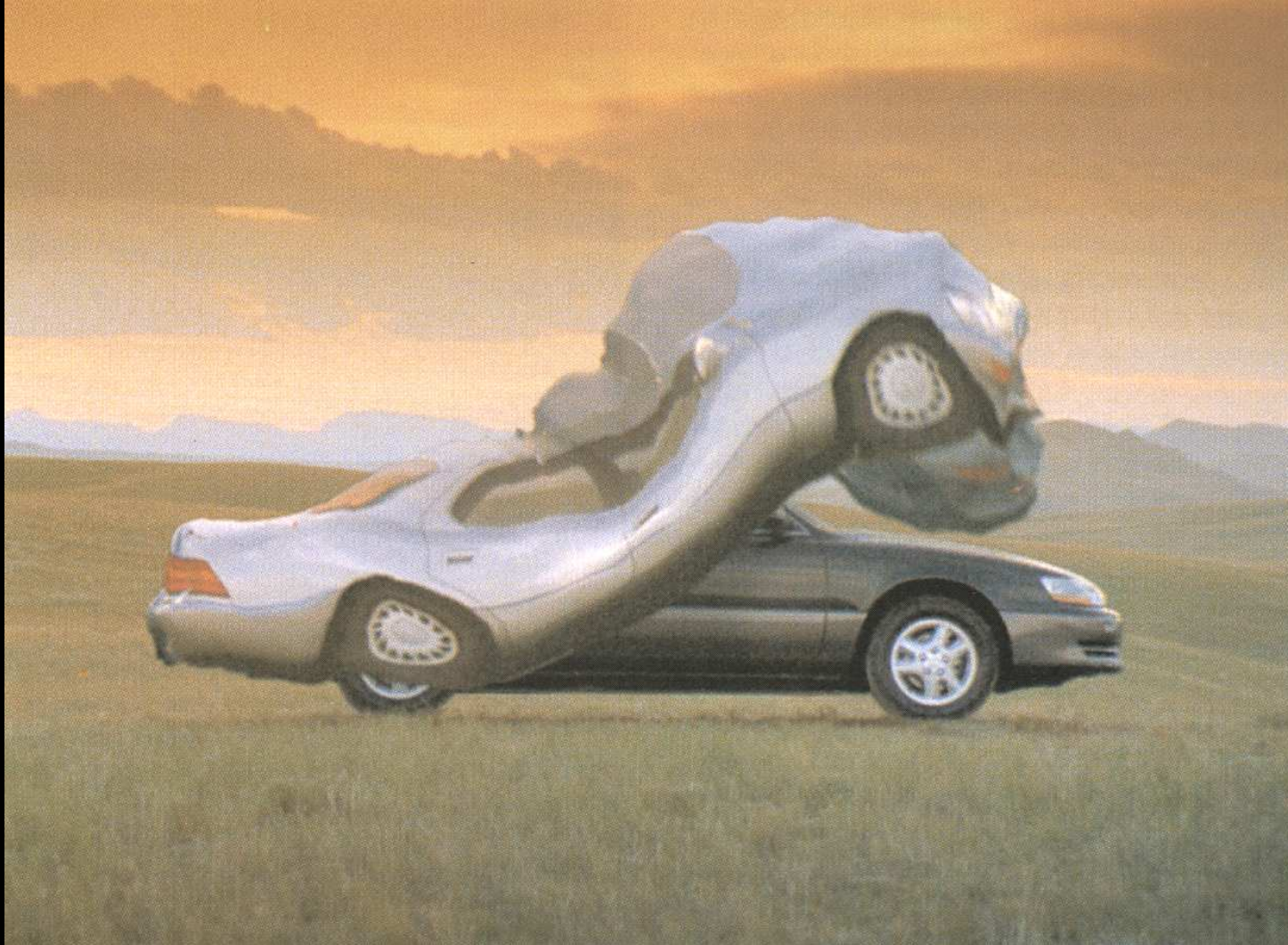
Particle System Forces

- Force fields
  - Gravity, wind, pressure
- Viscosity/damping
  - Liquids, drag
- Collisions
  - Environment
  - Other particles
- Other particles
  - Springs between neighboring particles (mesh)
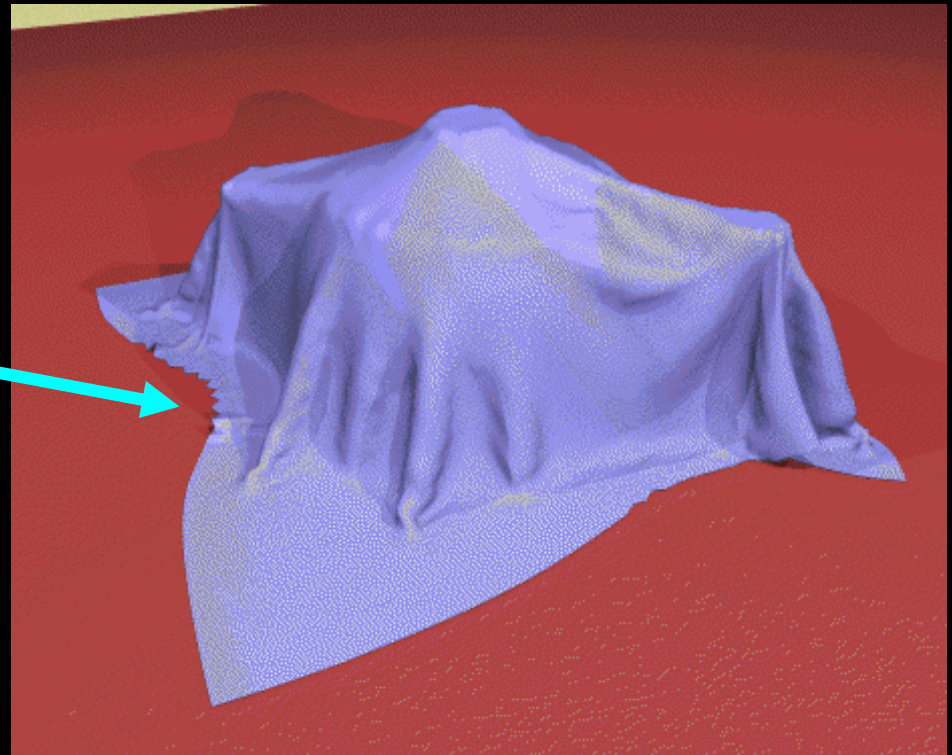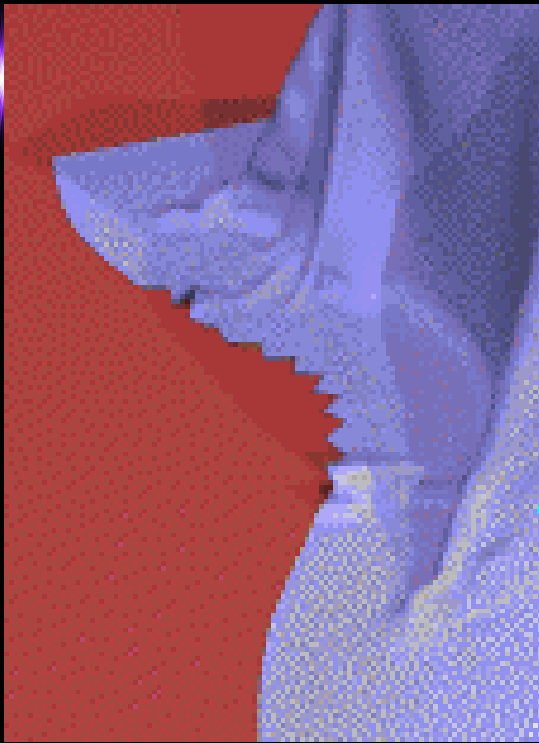 - Useful for cloth

Spring-Mass Systems

Cloth in 2D
Jello in 3D

Spring-Mass Systems

Increased Resolution of Mesh
     +Possible Shapes
     + Smoothness
     - Simulation time

Breen '95

Particle System Course Notes

- See Baraff + Witkin course notes:
    - Differential Equation Basics
    - Particle Dynamics