Engineering Research & Development Methodology

R&D Spectrum

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R&D Spectrum

- Basic research (Imagination phase)
- Applied research (Art phase)
- Development (Craft phase)
- Reflective Thinking

R&D Spectrum

- R&D can be categorized into three phases:
  - **1. Imagination Phase** (Basic research)—acquiring new knowledge without expected application of the knowledge.
  - **2. Art Phase** (Applied research)— taking a question out of the realm of imagination & creating something.
  - **3. Craft Phase** (Development)—evolving a current state of something by either modification to, or the creation of a product, process, system, or service.

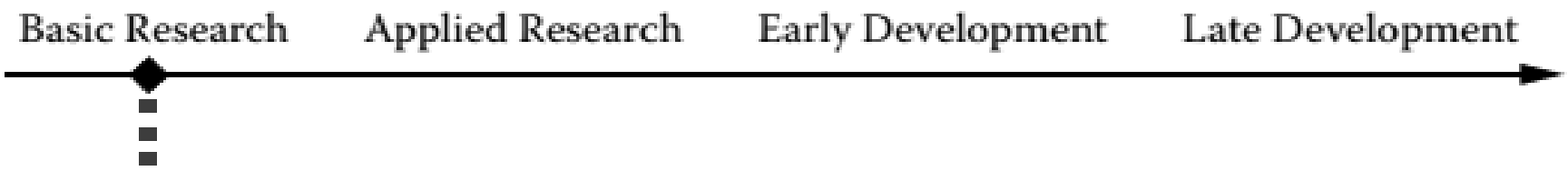

FIGURE 3.1
The R&D spectrum: Basic research.

Basic Research

- It can be thought of as the **quest for new knowledge without any expected application.**
- It is all about discovery, interpretation, & understanding.
- This is where **hypotheses are defined**, new thinking is explored, & ideas are brought to life.
- Its objective can be a spectrum of results
  - from **enhancing the knowledge of the individual** doing the research
  - to **enhancing the state of the art in a field**.

Basic Research

- **Nothing is built** at this point, & there are **no boundaries** except that eventually those ideas must be put down on paper if there is interest in moving them along the continuum.
- Actions taken at this stage could include
  - curiosity-driven investigation,
  - intellectual inquiry,
  - research,
  - publishing,
  - peer reviews, &
  - dialog, among others.

Basic Research

- **Oriented basic research**
  - a subcategory of basic research
  - expected to produce enough knowledge that can serve as *background* for applied research & eventual development activities.
- Although there is a linearity shown in the figure, the progression of R&D is **not linear**.
- The **progression** takes place both within research & within development.

Basic Research

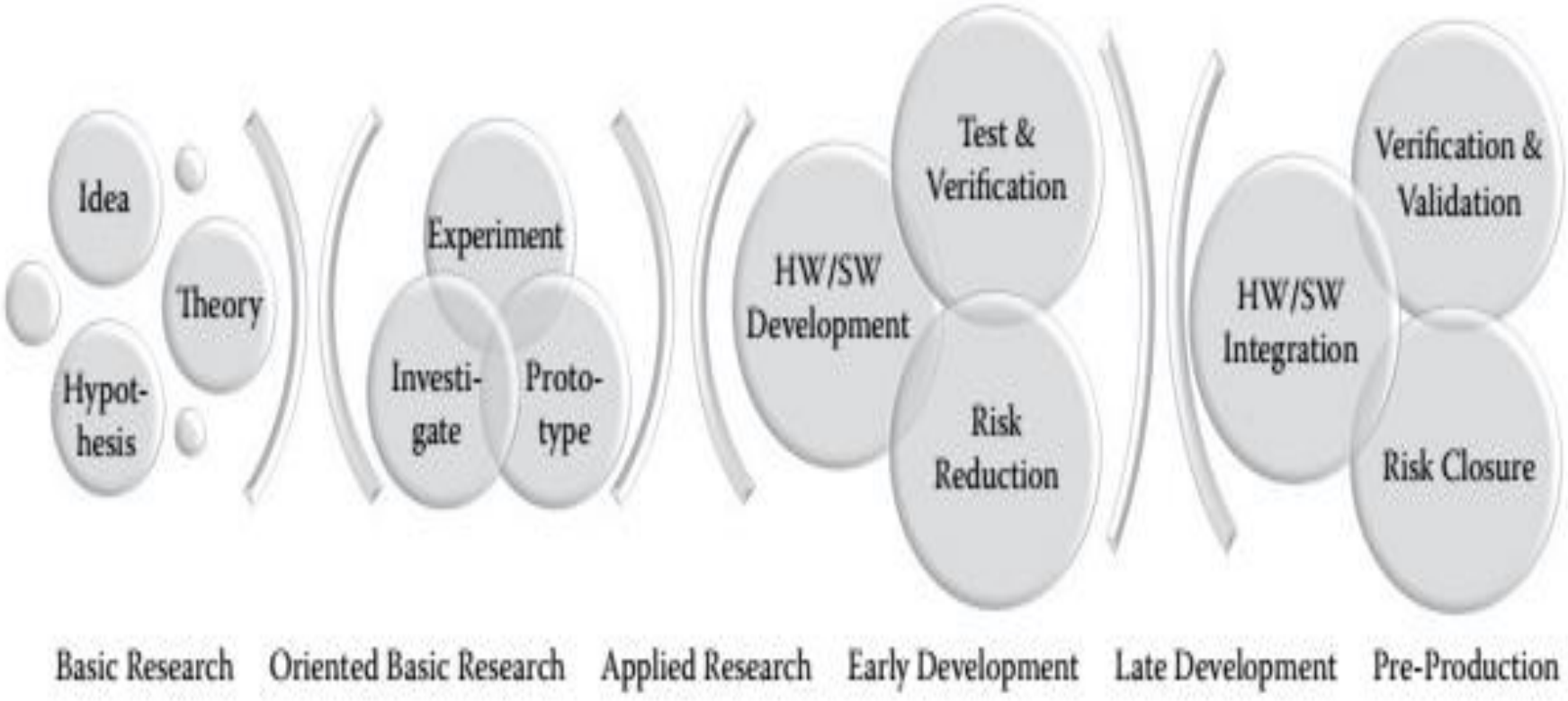

FIGURE 3.2

R&D progression.

Basic Research

- R&D progression can reveal:
  - a basic research activity may begin & end within that category without ever moving into the next category
  - It is possible to start in basic research, move through all the way to late development, & then loop back to an earlier phase if an experiment or prototype does not perform as planned
  - an activity may start in the applied research & move into early development
  - There is a relative synergistic relationship where results drive the progression.

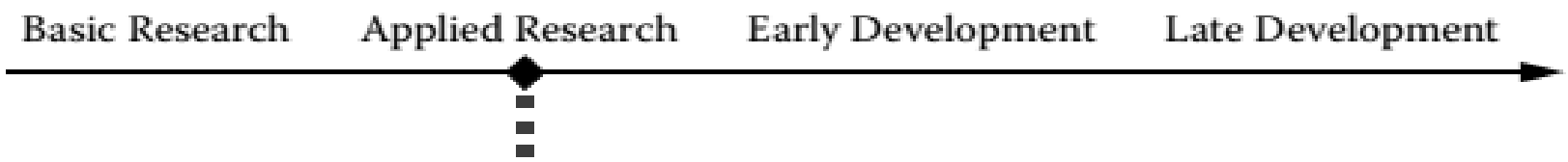

FIGURE 3.3
The R&D spectrum: Applied research.

Applied Research

- It can be thought of as the **art phase**, because its focus is on taking a question out of the realm of imagination & creating something.
- It is about the enhancement of knowledge to a recognized need or gap,
  - sometimes referred to as **strategic research**.
- It moves the idea to a **demonstration of those ideas** in an effort to close the gap of knowledge, fulfill a need, or meet an objective.

Applied Research

- During this phase,
  - ideas may lead to **experiments** meant to test & validate them, &
  - rudimentary **prototypes** may be built or ideas tested.
- Actions taken at this stage may include
  - research, publishing, peer reviews, dialog, or other defining activities;
  - however, they have a clear focus.

Applied Research

- This is a highly creative phase with a great deal of **risk** & a **low probability of success** in experimental validation.
- Successful activities in this phase are ready to move into development or what can be referred to as the *craft* phase, where the focus shifts more to form, fit, & function of an idea.

FIGURE 3.7
The R&D spectrum: Development.

Development

- It is directed toward **producing** materials, devices, systems, methods, process, software, etc.
- focused toward **evolving a current state of something** by either modification to, or the creation of, a product, process, system, or service.
- Typically focuses on:
  - carrying out **experiments**,
  - building **prototypes** or **models**,
  - developing & running **simulations**,
  - designing or redesigning **processes**, &
  - **testing**, **verifying**, & **validating** designs

Development

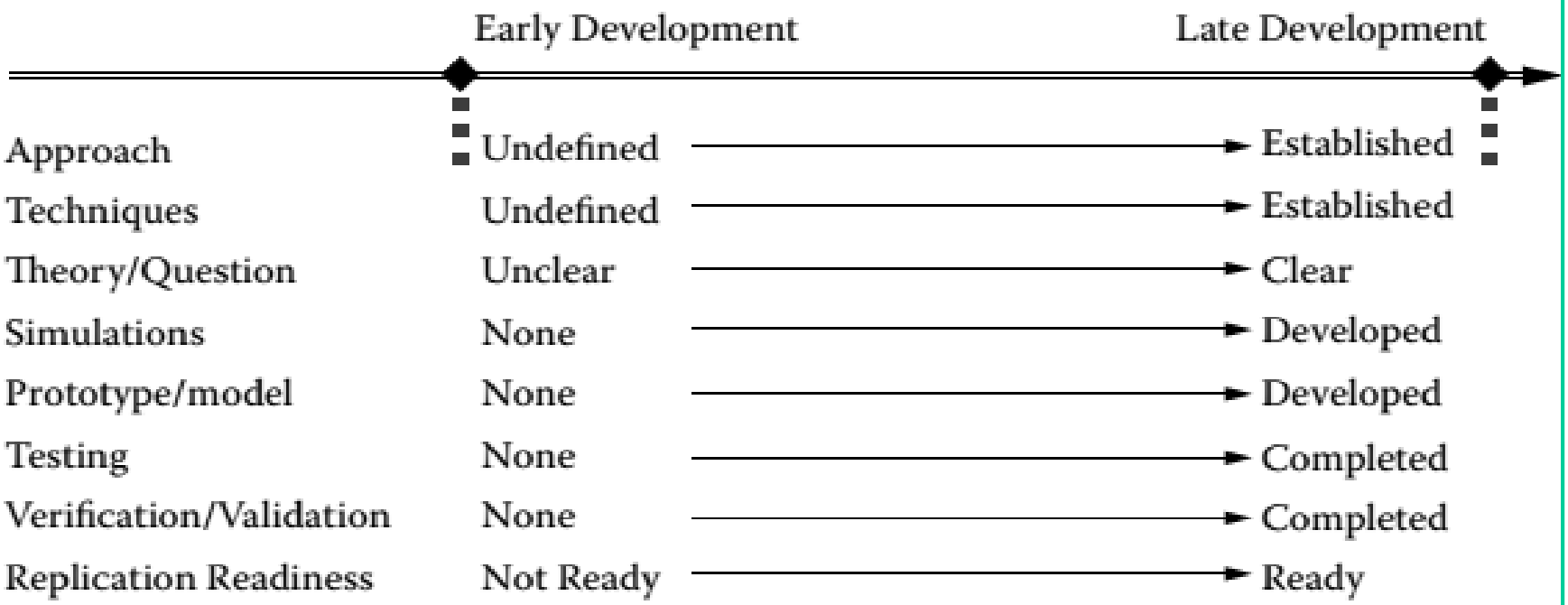

FIGURE 3.8
The R&D spectrum: Total.

Development

- The earlier in the development phase an activity is, the **less is known** about how to actually accomplish the change that is desired.
- The later in the development phase, the closer it is to **implementation readiness**.
- Once a successful test phase is complete, & the results verified in a manner that reflects the expected outcomes, it should be ready to move into an implementation or production environment.

Development

- **Incremental R&D**, making small changes along an existing trajectory, also straddles the continuum, but can extend out far into the production or operations areas.
- **Radical R&D**, taking a different approach to pursue a result that will be fundamentally & dramatically different, typically requires theoretical &/or basic research so it straddles the continuum from basic research through early development.
- It is almost impossible to separate the research from the development when a radical outcome is desired.

Development

Typical Steps in Development

- Setting **strategy**, trajectory, high-level **goals**, posing **questions** &/or forming **hypotheses**
- **Scheduling** & **budgeting** as relates to use of labor & materials resources needed to support prototyping or other experiments
- Identifying the appropriate **decision points** for when the work should no longer be pursued
- Searching relevant **literature**, discussions, comparative development activities across disciplines
- Preparing **simulations**, **models**, or **prototypes**
- Prioritizing & setting up **experiments**

Development

- **Typical Steps in Development**
  - **Testing**
  - **Recording** measurements, making calculations
  - **Verification**, **validation**, & quality checks
  - Completing **analysis** on the results
  - Modifying design, retesting as appropriate to reduce risk & progress toward goal
  - Stopping the work when appropriate
  - **Documenting** experimentation methods, change & configuration, & results
  - **Communicating** results

Reflective Thinking

- Major activities & the progression within Basic research , Applied research & Development
- The successful movement of research activities to development
- The looping back of the some research activities to the previous when required
- Typical steps in development

References

- Wingate, L.M.(2015).Project Management for Research & Development: Guiding Innovation for Positive R&D Outcomes